AERE WORKSHOP ON RECREATION DEMAND MODELING

The Association of Environmental and Resource Economists

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Introduction

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This introduction describes the objectives and organization of the first AERE Workshop conducted under EPA Cooperative Agreement CR-812056-01-0 in Boulder, Colorado May 17-18, 1985 and further describes the level of participation and reaction by participants to the workshop. The topic of the workshop was issues associated with modeling the demand and valuation of recreational resources. Three themes that are associated with the current research on the economics of valuing outdoor recreational resources provided the basis for organizing a day and a half of sessions at the workshop.

The first of these themes was in the modeling of the role of site attributes and determining the demand for recreational sites. There has been increased interest in the development of models for describing recreational behavior that take account of attributes that distinguish recreational sites. For example, in the case of water-based recreation, water quality would be one attribute that would influence the character and types of activities that could be undertaken in water-based recreation sites. By contrast, for hunting recreation, the density and types of game resources influencing the likelihood of successful hunting experiences would be an alternative kind of characteristic. In addition to these characteristics which fall under the direct control of those managing the recreational resources, there are also measures of congestion and the physical features of the facility which may in some cases be either directly or indirectly controlled. Three competing frameworks for modeling these site attributes have arisen in the current literature. They include the so-called varying parameter model, the hedonic travel cost model, and the development of generalized indirect utility function models. Since each of these frameworks has different data requirements and makes different implicit assumptions about the structure of individual preferences and the role of site attributes in them, it was judged to be quite important that we develop an understanding of the inter-relationship between the models and their potential uses in the valuation of these amenity resources.

Closely related in this modeling question is the issue, considered in the second session, of how to model the demands for recreational sites within a given region. Once again, the sites are likely to be differentiated by characteristics, but what is at issue is the strategy adopted in trying to represent an individual's selection of these sites when patterns of use may be such that only a subset of the sites are actually selected for recreational use. The description of the role of site substitution possibilities and the valuation of changes in site amenities in this context becomes quite important. For example, it is entirely possible that a change in the characteristics of one site may well lead to a change in the sites selected by individuals for their recreational choices. Thus, sites that were not used under one configuration of site attributes may be used under another and the welfare valuation problem becomes increasingly complicated if the framework used to describe the demand for sites and the role of substitution among sites does not accommodate this possibility.

Each of the three models described above offers the potential, with differing restrictive assumptions, for accommodating site substitution behavior. However, they do not reflect it in the general way that was described above. One model, for example, estimates the demand for site characteristics alone and not the sites. This implies that only one site is ultimately selected and all sites can be converted into equivalent units of recreational services. Thus, the selection of a site, once the conversion function is known, is apparent. Another of the models restrictively assumes that each individual visits all of the sites. The restrictive assumptions in these models raise the general question of how to model consumer demand theory allowing for corner solutions (i.e., the selection of zero consumption levels for some commodities). This, of course, introduces the substantive problems associated with welfare analysis in discrete choice situations. Thus, the interaction of all of these problems provided the basis for the second session. The issues here had a great deal in common with those in the first session and were discussed in a way that reflected that interaction.

The objective of the third session was to appraise our current understanding of the modeling of non-user values. Particular attention was focused on the implications of the conceptual definition of existence value and the ability to measure existence values. In addition, the implications of the theoretical definition of option value for its empirical estimates were also a part of the third session.

Over fifty participants attended the first workshop. The format for the workshop eliminated formal discussants of papers and instead relied upon interaction of authors, involvement of the session chairpersons, and commentary from the floor to draw out the inter-relationships between the papers. Copies of all of the papers were available to authors before the workshop and to all other participants at the outset of the workshop in a loosely bound format which facilitated presentation and commentary. Having access to the papers turned out to be essential to promoting interaction between authors and participants. All participating in the workshop who commented to the organizers suggested the discussion was lively and the interaction exceptionally interesting.

The attached papers represent the drafts of the papers submitted for the workshop. We will now be contactint Professor Ronald G. Cummings, one of the editors of Water Resources Research to determine if there is interest in devoting part of an issue to shortened versions of the papers.

The Logit Model and Exact Expected Consumer's Surplus Measures:

Valuing Marine Recreational Fishing*

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Abstract

A random utility model of recreational demand is developed which assumes that utility has a random component from the individual's perspective at the beginning of the season. The specific application is to marine recreational fishing along the Oregon coast. The model is used to derive an exact expected consumer's surplus measure. If the individual is risk neutral, this expected consumer's surplus measure can be interpreted as an option price; an option price is how much a fisherman would pay at the beginning of the season for the option of visiting a particular site even though he might not ever actually visit that site. This expected consumer's surplus measure is also related to the more conventional deterministic consumer's surplus measure.

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In this paper a multinomial logit model of recreational fishing demand is specified and estimated. The specific application is to marine recreational fishing in Oregon. The model is used to calculate the expected compensating and equivalent variations associated with changes in catch rates and those associated with the elimination of different fishing sites and modes (man-made structures, beach and bank, charter boat and private boat) along the Oregon coast. If the fisherman is risk neutral, these exact expected consumer's surplus measures can be interpreted as "option prices".[1] For example, the expected compensating variation for the eliminating of a site/mode is the amount a risk neutral fisherman would pay at the beginning of the season for the option of fishing at that particular site/mode. A fisherman's expected consumer's surplus for the elimination of a site/mode is an increasing function of the probability that he would have visited that site/mode and this expected consumer's surplus is positive even if he never would have actually visited the site. The expected compensating variation is also related to the more conventional deterministic compensating variation which is the amount an individual would be willing to pay (or have to be paid) to bring about (or accept) a change in the cost or characteristics of a site/mode if he knew he was going to choose that site/mode with certainty.

The random utility logit model is one of the few utility-theoretic models hhat can be estimated with the recreational data that is usually available. Most recreational demand data is collected by conducting on-site interviews at one or more sites. The Marine Recreational Fishery Statistics (MRFS) Survey used in this study is a prime example of one that conducted on-site interviews at a number of sites. In such a survey one observes each individual's destination on only one of their trips during the season. No attempt is made to determine where they went on their other trips. Given this type of data, one can only estimate the substitution possibilities among the alternative site/modes in a consistent utility-theoretic framework if one assumes that the utility function is additive across fishing **trips.**[2] The random utility logit model is one of few models that is consistent with this assumption but that does not unrealistically require that the fisherman visits the same site/mode on each trip.

The need for a utility-theoretic model is critical if the estimated demand functions are to be used to derive consumer's surplus measures. If one's intent is to just predict demand then it is not as critical that the estimated demand functions are consistent with an underlying utility function, but since the measurement of consumer's surplus is just a disguised attempt to measure utility itself, utility-theoretic consistency is necessary when welfare measures are estimated. Given this and given the type of recreational data usually available, policy makers require a method of deriving exact expected consumer surplus measures from the logit model; methods to do this have recently been developed by McFadden (1981), Small and Rosen (1981) and Haneman (1985). This paper provides an empirical **example.**[3]

Unlike most random utility logit models, the model presented in this paper assumes that utility has a random component from the individual's perspective at the beginning of the **season.**[4] This alternative interpretation of the random utility logit model is what allows us to interpret the exact expected consumer's surplus measures as option prices.

Section I outlines a multinominal logit model of site/mode choice, while Section 11 describes the data and the empirical results. The derivation of exact expected compensating (and equivalent) variations from the logit model is explained in Section III. As an example, these are calculated for the elimination of salmon and other fishing opportunities due to pollution in the

Columbia river. The expected welfare effects of a salmon enhancement program are also reported. Section III concludes with a discussion of the relationship between the expected and deterministic compensating variation. Section IV is a brief concluding summary.

I. A Multinomial Logit Model of Site/Mode Choice

For each individual in the sample we observe only one fishing trip where we know which site/mode the individual chose. The individual chose this trip from among the J x M alternatives where J is the number of alternative sites (coastal counties in Oregon) and M is the number of alternative modes.

Let the probability that individual i chooses site j mode m on a given trip be π_{jmi} where $\sum_{j=1}^{J} \sum_{m=1}^{M} \pi_{jmi} = 1$. Therefore, if there are N independent individuals in the sample and we only observe one trip for each individual, the likelihood function for the sites chosen by the N individuals is

$$(1) \quad L = \prod_{i=1}^{N} \prod_{j=1}^{J} \prod_{m=1}^{M} \pi_{jmi}^{\;y_{jmti}}$$

where $y_{jmti} = 1$ if individual i chooses site j mode m on the t^{th} trip and zero otherwise.

The standard logit model derives the π_{jmi} from a random utility model (RUM) such that the probabilities are a function of the costs of visiting each of the site/modes and the catch rates at each of the site/modes.[5] Assume that the utility individual i receives if he chooses to fish at site/modes jm is

$$(2) \quad U_{jmti} = U(B_i, p_{jmi}, a_{jm1}, a_{jm2}, \ldots, a_{jm5}) + \varepsilon_{jmti}$$

where

B_i is individual i's budget for the period in which each trip takes place

P_{jmi} is the cost of a trip to site j mode m for individual i

a_{jmk} is the average catch rate for species k at site j mode m, k = 1, 2, ... 5. Species 1 = Salmon, 2 = Perch, 3 = Smelt and Grunion, 4 = Flatfish, and 5 = Rockfish/Bottomfish

and

The random component ε_{jmti} is assumed known to the individual on the day each trip is taken, but ε_{jmti} varies across individuals, site/modes and from trip to trip. At the beginning of the season, the individual does not know the values ε_{jmti} will take on each trip. The variable ε_{jmti} is therefore random from the individual's perspective at the beginning of the season but deterministic on the morning each trip is taken. The variable ε_{jmti} is completely random from our perspective. The vector $\varepsilon_{it} \equiv [\varepsilon_{jmti}]$ is therefore a set of random variables with some joint c.d.f. $F\varepsilon(\varepsilon_{it})$.

Equation (2) is a conditional indirect utility function that assumes utility is additive both across site/modes and trips. Conditional utility, U_{jmti}, has a random component from our perspective and from the individual's perspective at the beginning of the season. On each trip, the individual always chooses that site/mode that provides the greatest utility, but the utility maximizing site/mode varies from trip to trip in a way the individual cannot predict. The standard logit model specifically assumes that[6]

(2a) $U_{jmti} = \beta_0 B_i - \beta_0 P_{jmi} + \beta_1 a_{jm1} + \beta_2 a_{jm2} + \beta_3 a_{jm3} + \beta_4 a_{jm4} + \beta_5 a_{jm5} + \varepsilon_{jmti}$

The conditional indirect utility function (2a) implies that the choice of alternatives is independent of B_i; i.e., there is no income effect. This specification was chosen because there is no data on B_i. The parameter β_o is the constant marginal utility of money. The probability that individual i will choose site j mode m is therefore

$$(3) \quad \pi_{jmi} = \text{Prob}[U_{jmti} > U_{\ell sti} \quad \forall\, \ell, s]$$

The standard logit model assumes that the vector of random variables ε_{it} has an Extreme Value Distribution; i.e., that the joint c.d.f. is

$$(4) \quad F\varepsilon(\varepsilon_{it}) = \exp[-\sum_{j=1}^{J} \sum_{m=1}^{M} e^{-\varepsilon_{jmti}}]$$

It can be shown that

$$(5) \quad \pi_{jmi} = 1/ \sum_{\ell=1}^{J} \sum_{s=1}^{M} e^{[-\beta_0(p_{\ell si} - p_{jmi}) + \beta_1(a_{\ell s1} - a_{jm1}) + \beta_2(a_{\ell s2} - a_{jm2}) + \dots + \beta_5(a_{\ell s5} - a_{jm5})]}.$$

The likelihood function in terms of the data and the β parameters is obtained by substituting (5) into (1). The maximum likelihood estimates of the parameters are those values of the β parameters that maximize this likelihood function. These are most easily obtained by maximizing the log of the likelihood function (6) rather than the likelihood function itself.

$$(6) \quad \ln L = \sum_{i=1}^{N} \sum_{j=1}^{J} \sum_{m=1}^{M} y_{jmti} \ln \pi_{jmi}$$

$$= - \sum_{i=1}^{N} \sum_{j=1}^{J} \sum_{m=1}^{M} y_{jmti} \ln \sum_{\ell=1}^{J} \sum_{s=1}^{M} e^{[-\beta_0(p_{\ell si} - p_{jmi}) + \beta_1(a_{\ell s1} - a_{jm1}) + \beta_2(a_{\ell s2} - a_{jm2}) + \dots + \beta_5(a_{\ell s5} - a_{jm5})]}$$

II. Data and the Empirical Results

The data come from the 1981 MRFS intercept survey along the Pacific coast (U.S. Department of Commerce, NOAA (1983)). Fishermen were intercepted and interviewed at numerous sites along the Oregon coast. Information was collected about the intercept trip, particularly catch data, which was the main purpose of the survey. Data was collected on the total number of trips each individual took during the season however, except for the intercept trip, there was no data collected on the distribution of those trips across sites. Other than catch rates, the only individual-specific information is county of residence and expenses on the intercept trip. This lack of individual-specific data, while unfortunate, simplifies estimation because in this case the log of the likelihood function (6) can be written in the simplified form

$$(6a)\quad \ln L = \sum_{c=1}^{C} \sum_{j=1}^{J} \sum_{m=1}^{M} Y_{jmc} \ln \pi_{jmc}$$

$$= - \sum_{c=1}^{C} \sum_{j=1}^{J} \sum_{m=1}^{M} Y_{jmc} \left\{ \ln \sum_{\ell=1}^{J} \sum_{s=1}^{M} e^{[-\beta_0(p_{\ell sc} - p_{jmc}) + \beta_1(a_{\ell s1} - a_{jm1}) + \beta_2(a_{\ell s2} - a_{jm2}) + \cdots + \beta_5(a_{\ell s5} - a_{jm5})]} \right\}$$

where

C is the number of counties of origin (there are 36 counties in Oregon)

π_{jmc} is the probability that an individual from origin county c will choose site j mode m

and

Y_{jmc} is the number of individuals who took trips from origin county c to site j mode m

Since C is much smaller than N, the maximum of (6a) can be computed more rapidly than the maximum of (6).

The Oregon coast was divided into seven macro sites (coastal counties). The sites, south to north, are Curry, Coos, Douglass, Lane, Lincoln, Tilamook, and Clatsop counties. The 5,855 Oregon residents in the sample came from all 36 counties in the state.

Assume that the cost of a trip to site j mode m for individuals from county c (p_{jmc}) equals travel costs plus the value of time in transit plus site/mode cost; i.e.

(7) p_{jmc} = 2(Distance from c to j).112 + (2(Distance c to j)/40)3.35
+ average on-site/mode costs at site j mode m
+ (required nights of lodging)(average per-night lodging costs)

where

.112 was the per-mile cost of operating an automobile in 1981 (U.S. Bureau of the Census (1981))

Distances were measured from the population center of county c to the nearest coastal point in county j

$3.35 is the 1981 minimum wage (U.S. Bureau of the Census (1981))[7]

40 mph was assumed to be the average speed of travel

Required nights of lodging were assumed to be zero if the distance from c to j was less than 150 miles, one if between 150 and 300 miles and two if between 300 and 450 miles

The average per-night lodging costs were $19.32 (Rowe, et al (1985))

The average mode costs were $3.87 for man-made structures, $2.87 for beach and bank, $52.80 for charter boat and $22.83 for private boat (Rowe, et al (1985))

A few representative costs are reported in Table 1. The costs in the sample vary from $4.83 to $329.24. The high range follows from several considerations: it is much cheaper to fish near home; off-shore fishing is much more expensive than on-shore fishing; fishing from man-made structures is one dollar more expensive than beach and bank fishing because there is often a fee to fish from a pier and the marginal cost of charter boat fishing is $29.97 higher than the marginal cost of fishing from a private boat.

The catch rates for the five most important species are reported in Table 2.[8] There is a substantial variation in catch rates across sites, modes and species. Note that most salmon are caught from boats and that salmon catch rates are higher for charter boats than for private boats. Charter boat operators have more information about the location of this important game fish. Perch, on the other hand, are caught mostly from shore modes.

The data were used to find those values of β that maximizes (6a). A Newton-type search algorithm was used.[9] The maximum likelihood parameter estimates are reported in Table 3. On the basis of likelihood ratio tests, the Costs Only Model explains the allocation across site/modes significantly better than the Random Allocation Model and the Costs and Catch Rate Model explains significantly better than the Costs Only Model. Both costs and catch rates are important determinants of where an individual will fish. Notice that the coefficient on perch (β_2) is negative; the negative sign may be indicating that the presence of perch makes it less likely that more desirable species are present. The negative coefficient does not mean that fisherman dislike perch per se.

The estimated probabilities for the different site/mode alternatives (5) are reported in Table 4 for individuals from five representative counties of origin. Notice how these estimated probabilities depend on distance, mode costs and catch rates. Private boats are more "attractive" than charter boats, probably due to the cost differential, and beach and bank is more attractive than man-made structures. Distance is obviously important and on-shore is more attractive than off-shore.

III. Exact Expected Consumer Surplus Measures

A. Theory

Let $P_c^{\circ} \equiv [p_{jmc}^{\circ}]$ be the initial matrix of costs for an individual from county c,

$P_c' \equiv [p_{jmc}']$ be the new matrix of costs for an individual from county c,

$A^{\circ} \equiv [a_{jmk}^{\circ}]$ be the initial matrix of site/mode catch rates

and

$A' \equiv [a_{jmk}']$ be the new matrix of site/mode catch rates.

McFadden (1981), Small and Rosen (1981) and Hanemann (1985) have each shown that for the logit model outlined in this paper the expected per trip compensating variation (and equivalent variation) associated with a change from (P_c°, A°) to (P_c', A') is

$$(8)\quad CV_c = EV_c = \frac{1}{\beta_0}\left[\ln\left\{\sum_{j=1}^{J}\sum_{m=1}^{M} e^{(-\beta_0 p_{jmc}^{\circ} + \beta_1 a_{jm1}^{\circ} + \beta_2 a_{jm2}^{\circ} + \cdots + \beta_5 a_{jm5}^{\circ}}\right\} - \ln\left\{\sum_{j=1}^{J}\sum_{m=1}^{M} e^{(-\beta_0 p_{jmc}' + \beta_1 a_{jm1}' + \beta_2 a_{jm2}' + \cdots + \beta_5 a_{jm5}')}\right\}\right]$$

for an individual from county c. The CV_c and EV_c are equal because the chosen conditional indirect utility function (2a) assumes there is no income effect.

Following Hanemann (1985), the derivation of equation (8) proceeds as follows. Remember that

$$U_{jmti} = \beta_0 B_i - \beta_0 P_{jmi} + \beta_1 a_{jm1} + \beta_2 a_{jm2} + \cdots + \beta_5 a_{jm5} + \varepsilon_{jmti} \qquad (2a)$$

is individual i's conditional indirect utility function on the t^{th} trip for site j mode m. Therefore the unconditional indirect utility function for individual i is

$$(9)\quad v_{it} = v(P_i, A, \beta_i, \varepsilon_{it})$$

$$= \max[U_{11i}, U_{12i}, \ldots, U_{1mi}, \ldots, U_{j1i}, \ldots, U_{jmi}, \ldots, U_{J1i}, \ldots, U_{JMi}]$$

$$= \max[U(B_i, P_{11i}, a_{111}, a_{112}, \ldots, a_{115}) + \varepsilon_{11ti}, \ldots, U(B_i, P_{jmi}, a_{jm1}, a_{jm2}, \ldots, a_{jm5}) + \varepsilon_{jmti}, \ldots, U(B_i, P_{JMi}, a_{JM1}, a_{JM2}, \ldots, a_{JM5}) + \varepsilon_{JMti}]$$

The variable v_{it} is the utility obtained by individual i if he maximizes his utility when confronted with the choice set $(P_i, A, B_i, \varepsilon_{it})$. Note that v_{it} is deterministic from the individual's point of view on the day the trip is taken, but a random variable from our perspective and a random variable from the individual's perspective at the beginning of the season. Since v_{it} is a random variable, we need to use its expected value to determine the expected welfare impact of a change from $(P_i^{\circ}, A^{\circ}, B_i)$ to (P_i', A', B_i). The expected value of v_{it} (V_i) is

$$(10)\quad V_i = V(P_i, A, B_i) = E[v(P_i, A, B_i, \varepsilon_{it})]$$

$$= E\left\{\max[U_{11i}, U_{12i}, \ldots, U_{1Mi}, \ldots, U_{j1i}, \ldots, U_{jMi}, \ldots, U_{J1i}, \ldots, U_{JMi}]\right\}$$

Note that V_i doesn't depend on t. The variable V_i is the expected maximum utility associated with the choice set (P_i, A, B_i).

Equation (10) can be used to define the expected compensating variation (CV_i) and expected equivalent variations (EV_i) in the random utility framework. Define the CV_i and EV_i such that

$$(11)\ V(P_i', A', B_i + CV_i) = V(P_i^{\circ}, A^{\circ}, B_i)$$

and

$$(12)\ V(P_i', A', B_i) = V(P_i^{\circ}, A^{\circ}, B_i - EV_i)$$

Defined in this way, the CV_i is the compensation (or payment) associated with the change that would make the expected maximum utility after the change the same as it was before the change. If (P_i', A') is preferred to (P_i°. A°) then the absolute value of CV_i is the amount a risk neutral individual i would pay at the beginning of the season for the option of facing choice set (P_i', A') rather than choice set (P_i°, A°) on one of his trips.[10] Since utility is additive across trips, individual i will pay a total of $T_i CV_i$ at the beginning of the season for the option of facing choice set (P_i', A') for the entire season, where T_i is the number of trips individual i will take during the season. If (P_i°, A°) is preferred to (P_i', A') then CV_i is how much a risk neutral individual i would have to be paid at the beginning of the season to voluntarily accept the choice set (P_i', A') on one of his trips. The EV_i (12) is the compensation (or payment) associated with the initial state that would make individual i's expected maximum utility without the change equivalent to his expected maximum utility with the change.

Given the conditional indirect utility function (2a) and utilizing (11) and (12), Hanemann (1985) has shown that

$$(13)\ CV_i = EV_i = \frac{1}{\beta_0} [V_i^{\circ} - V_i']$$

Intuitively, $[V_i^\circ - V_i']$ is the difference between the expected maximum utility in the two states. Since β_0 is the constant marginal utility of money, $(1/\beta_0)$ is the inverse of the marginal utility of money. Therefore, multiplying $[V_i^\circ - V_i']$ by $(1/\beta_0)$ converts the expected utility change into a money metric of the expected change. The CV_i equals the EV_i because there is no income effect.

If it is assumed that ε_{it} in the conditional indirect utility function (2a) has an Extreme Value Distribution, the logit assumption, then it can be shown that

$$(14)\quad V_i^\circ = \beta_0 B_i + \ln \sum_{j=1}^{J} \sum_{m=1}^{M} e^{(-\beta_0 p^\circ_{jmi} + \beta_1 a^\circ_{jm1} + \beta_2 a^\circ_{jm2} + \cdots + \beta_5 a^\circ_{jm5})}$$

and that

$$(15)\quad V_i' = \beta_0 B_i + \sum_{j=1}^{J} \sum_{m=1}^{M} e^{(-\beta_0 p'_{jmi} + \beta_1 a'_{jm1} + \beta_2 a'_{jm2} + \cdots + \beta_5 a'_{jm5})}$$

The equation for the CV_c and EV_c (8) is obtained by substituting (14) and (15) into (13) and noting that all individuals from the same county are effectively identical.[11]

B. An Example: The Estimated Compensating Variations, CV_c's, Associated with Increased Pollution in the Columbia River

Equation (8) can be used to calculate the CV_c's associated with the elimination of on-shore, off-shore, and all fishing opportunities in Clatsop county (the Oregon county at the mouth of the Columbia river). An increase in agricultural and industrial pollution in the Columbia river could drastically affect this fishery. The CV_c's for the Clatsop fisheries, along with for comparison the CV_c's for the elimination of the fisheries in Douglass and curry, are reported in Table 5 for seven representative counties of origin. In general, note the importance of distance; that the CV_c's for the on-shore fishery are significantly larger than CV_c's for the off-shore fishery and that each CV_c for the elimination of both modes is larger than the sum of the CV_c's for the elimination of each mode separately.

A fisherman from Clatsop county will pay $14.60 at the beginning of the season for the option of being able to fish from an on-shore mode in Clatsop county on one of his trips, a fisherman from Portland (Multnomah county) will pay $4.55 for the same option and a fisherman from Curry county will pay effectively nothing for this option. Compare these with the probability that an individual would have chosen an on-shore mode in Clatsop county (see Table 4); the probability for Clatsop residents is .63, .27 for Portland residents and effectively zero for residents of Curry county.

Fisherman will pay significant amounts for the option of fishing at modes that they might not ever actually visit. For example, a fisherman from Multnomah would have paid $4.55 for the option of shore fishing in Clatsop, county on a single trip even though the probability that the individual would have actually chosen this site/mode is only .27. This CV_c is significant from a policy perspective because Multnomah residents took an estimated 211,300 fishing trips in 1981 (Rowe et al (1985)).

Rather than assuming that pollution in the Columbia river affects all marine species one might hypothesize that it only affects salmon. The CV_c's for the elimination of the salmon fishery in Clatsop county are reported in Table 6 for individuals from seven representative counties of origin. Comparing these estimates with those in Table 5 and remembering that most salmon fishing is from off-shore modes, one sees that salmon explain approximately sixty percent of the consumer's surplus associated with the Clatsop off-shore fishery. Since, unlike other species in Clatsop county, most salmon are captured by charter boats (see Table 2), one suspects that much of the potential consumer's surplus from the salmon fishery has been captured by the charter boat operators. Table 7 reports the CV_c's for a salmon enhancement program in the Columbia river that increases the off-shore salmon catch rates in Clatsop county from 1.27 to 2.27 for charter boats and from .70 to 1.70 for private boats. These CV_c's are negative indicating the amount the individuals would pay to bring about the change. These estimates are all larger than the corresponding CV_cs for the elimination of salmon in Clatsop county (Table 6) because a lot of the increased catch is captured by private boats and the marginal cost of fishing from a private boat is considerably less than the marginal cost of fishing from a charter boat.

C. Relating the Expected Compensating Variation, CV_i, to the Deterministic Compensating Variation

Most of the empirical consumer's surplus literature that deals with continuous choices calculates compensating and equivalent variations implicitly assuming that the utility function does not have a random component; that is, the calculated consumer's surplus measures implicitly assume that the individual knows with certainty what bundle they will consume both before and after the exogeneous change in prices and characteristics. We will refer to these measures as deterministic consumer's surplus measures and consider deterministic compensating variations. The discrete choice analog to the continuous choice deterministic compensating variation is the compensation (or payment) associated with a change that would make the individual's utility after the change equal to his utility before the change given that the individual knows with certainty which of the discrete alternatives will be chosen both before and after the change. The intent of this section is to define deterministic compensating variations in the discrete choice model, calculate them for a salmon enhancement program, and then relate these deterministic discrete choice compensating variations to the expected compensating variations (CV_i's) that were derived from our RUM.

Let us begin with a simple case where the individual is choosing site j mode m with certainty and then the catch rates at the site increase all costs and all other catch rates remaining constant. The individual will obviously continue to choose site j mode m with certainty. An example would be an individual who chose the charter boat mode in Clatsop county with certainty and then, ceteris paribus, the charter boat catch rate for salmon in Clatsop county increases. It is of interest to ask how much this individual would have paid per trip to increase this single catch rate. Define the deterministic compensating variation associated with an improvement in the characteristics of the site/mode, jm, that the individual would have chosen with certainty both before and after the change, $DCV_i(jm/jm)$, as

$$(16)\quad U(B_i,\ p^{\circ}_{jmc},\ a^{\circ}_{jm1},\ a^{\circ}_{jm2},\ \ldots,\ a^{\circ}_{jm5}) + \cancel{\varepsilon_{jmti}}$$

$$= U(B_i + DCV_i(jm/jm),\ p^{\circ}_{jmi},\ a'_{jm1},\ a'_{jm2},\ \ldots,\ a'_{jm5}) + \cancel{\varepsilon_{jmti}}$$

where

$$U(B_i,\ p^{\circ}_{jmi},\ a'_{jm1},\ a'_{jm2},\ \ldots,\ a'_{jm5}) > U(B_i,\ p^{\circ}_{jmi},\ a^{\circ}_{jm1},\ a^{\circ}_{jm2},\ \ldots,\ a^{\circ}_{jm5})$$

Note that the random components **cancel.**[12] If the conditional indirect utility function (2) has the linear form (2a), (16) can be solved for the deterministic compensating variation

$$(17)\ DCV_i(jm/jm) = 1/\beta_0[\beta_1(a^{\circ}_{jm1} - a'_{jm1}) + \beta_2(a^{\circ}_{jm2} - a'_{jm2}) + \beta_3(a^{\circ}_{jm3} - a'_{jm3}) + \beta_4(a^{\circ}_{jm4} - a'_{jm4}) + \beta_5(a^{\circ}_{jm5} - a'_{jm5})]$$

In the case of a salmon enhancement program that only affects site j mode m, $a^{\circ}_{jmk} = a'_{jmk}$ k = 2, 3, . . . , 5. Therefore, given our parameter estimates and assuming the salmon catch rate increases by one

$$(17a)\ DCV_i(jm/jm) = DCV(jm/jm) = 1/\beta_0[\beta_1(a^{\circ}_{jm1} - a'_{jm1})]$$

$$= 1/.0681\ [.9770(1)] = \$14.34$$

One more salmon per trip is worth $14.34 per trip if the individual would have chosen this alternative with certainty before the change. Note that this magnitude does not depend on the individual's county of origin or the specific site mode considered.

Relating this deterministic compensating variation, DCV(jm/jm), to the expected compensating variation associated with the same improvement in the characteristics of site j mode m, $CV_i(jm)$, Hanemann (1983) has shown that

$$(18)\ CV_i(jm) \approx \pi_{jmi}\ DCV(jm/jm)$$

The expected compensating variation, $CV_i(jm)$, derived from the RUM is smaller than the deterministic compensating variation, DCV(jm/jm), because of the uncertainty associated with the choice of site/modes. This approximation has a lot of intuitive appeal and if we didn't already know DCV(jm/jm) it could be used to approximate it given estimates of the $CV_i(jm)$ and the estimated probabilities, π_{jmi}.

Equations (16) and (17) identified the deterministic compensating variation associated with an improvement in the site/mode that the fisherman was initially choosing with certainty. Relating the CV_i to its deterministic equivalent is much more complex if the quality of the site/mode that was initially chosen with certainty declines because then we cannot be sure which site/mode the individual will choose after the change. Consider, for example, a case where pollution eliminates just the beach and bank mode in Clatsop county. It is of interest to ask how much an individual will pay per trip to stop the elimination of the beach and bank mode in Clatsop county if that individual would have chosen that site/mode with certainty. In this case, we, know for certain that the individual is precluded from visiting the eliminated site/mode, but we don't know for certain which alternative will be chosen if the trip still occurs. However, we can identify the deterministic compensating variation associated with an individual who initially chose site j mode m with certainty and who chooses site ℓ mode s with certainty after site j mode m is eliminated as

$$(19)\quad U(B_i, p^{\circ}_{jmi}, a^{\circ}_{jm1}, a^{\circ}_{jm2}, \ldots, a^{\circ}_{jm5}) + \varepsilon_{jmti}$$
$$= U(B_i + DCV_{it}(jm/\ell s), p'_{\ell si}, a'_{\ell s1}, a'_{\ell s2}, \ldots, a'_{\ell s5}) + \varepsilon_{\ell sti}$$

If the conditional indirect utility function (2) has the linear form (2a), (19) can be solved for the deterministic compensating variation

$$(20)\quad DCV_{it}(jm/\ell s) = (p'_{\ell si} - p^{\circ}_{jmi}) + 1/\beta_0[\beta_1(a^{\circ}_{jm1} - a'_{\ell s1}) + \beta_2(a^{\circ}_{jm2} - a'_{\ell s2})$$
$$+ \beta_3(a^{\circ}_{jm3} - a'_{\ell s3}) + \beta_4(a^{\circ}_{jm4} - a'_{\ell s4}) + \beta_5(a^{\circ}_{jm5} - a'_{\ell s5}) + \varepsilon_{jmti} - \varepsilon_{\ell sti}]$$

The deterministic compensating variation, $DCV_{it}(jm/\ell s)$, is how much individual i will pay on trip t to stop the elimination of site j mode m if he would have chosen site j mode m with certainty before it was eliminated and site ℓ mode s with certainty after it was eliminated. For example, using (20) and the parameter estimates, one can calculate that the deterministic compensating variation for the elimination of beach and bank fishing in Clatsop county is \$28.23 + $(\varepsilon_{72ti} - \varepsilon_{62ti})/.0681$ for fisherman i from Clatsop county who switches with certainty to the beach and bank mode in Tilamook. Of the \$28.32, \$23.49 is attributable to the increased travel cost and \$4.74 to the fact that the quality of beach and bank fishing is lower in Tilamook county. If the same individual was forced to switch to the private boat mode in Douglass county the $CV_{it}(jm/\ell s)$ would be \$101.43 + $(\varepsilon_{72ti} - \varepsilon_{34ti})/.0681$. Of the \$101.43, \$99.02 is attributable to increased travel cost, \$19.96 is attributable to the switch to the more expensive mode and minus \$16.55 is attributable to the fact that the quality of the fishing improves. Note that each $CV_{it}(jm/\ell s)$ can only be determined up to its random component, $((\varepsilon_{jmti} - \varepsilon_{\ell sti})/.0681)$.

Relating the CV_i for the elimination of site j mode m, $CV_i(jm)$, to the $DCV_{it}(jm/\ell s)$'s it can be shown that one obtains the intuitively appealing result that[13]

$$(21)\quad CV_i(jm) \approx \sum_{\ell=1}^{J} \sum_{s=1}^{M} \pi_{\ell si}^{jm}\, DCV_{it}(jm/\ell s) \qquad \text{except when } j=\ell \text{ and } m=s$$

where

$\pi_{\ell si}$ is the probability that individual i will choose site ℓ mode s on a given trip if site j mode m is no longer available.

The expected compensating variation, $CV_i(jm)$, weights each deterministic compensating variation, $DCV_{it}(jm/\ell s)$, by the probability that it measures the welfare impact of the actual switch. The expected compensating variations for the elimination of beach and bank fishing in Clatsop county, $CV_i(jm)$, can be calculated using (8). It is $6.48 for fishermen from Clatsop county, $2.40 for fishermen from Multnomah county and effectively zero for fishermen from Douglass county. The probabilities, $\pi^{jm}_{\ell si}$, can be calculated using (5) with J and M reduced to reflect the elimination of site j mode m. However, in this case, knowledge of the $CV_i(jm)$ and the $\pi^{jm}_{\ell si}$ is not sufficient to approximate the $DCV_i(jm/\ell s)$.

If utility has a random component, the expected compensating variation, rather than the deterministic compensating variation, is the preferred welfare measure. The deterministic measure is only appropriate if we know with certainty what the individual will do. This raises some serious questions about deterministic consumer's surplus measures that are derived from constrained deterministic utility maximization models but where the estimated system of demand functions has a random component. The random component means that the individual's behavior is not known with certainty so expected, rather than deterministic, consumer's surplus measures are the appropriate welfare measure. The implicit assumption that utility is deterministic is untenable once the random component has been added to the demand functions. [14]

IV. Conclusion

A RUM of recreational demand is developed which makes the conventional assumption that utility is random from the investigator's perspective and unlike other random utility models also assumes that utility has a random component from the individual's perspective at the beginning of the season. The model is used to derive the exact expected consumer's surplus measures associated with changes in the costs and characteristics of the different site/modes. The assumption that utility is random from the individual's perspective at the beginning of the season implies that the expected consumer's surplus measures can be interpreted as option prices if the fisherman is risk neutral. If a site/mode might increase in quality, the associated expected compensating variation is how much a risk neutral fisherman would pay per trip at the beginning of the season for the option of experiencing this increase in quality even though he might not ever choose to actually visit that site/mode. If a site/mode might decrease in quality, the associated expected compensating variation is how much a risk neutral fisherman would pay per trip for the option of not having to experience this quality decline even though he might not ever actually choose to visit that site/mode. These option prices vary across sites for a given individual as a function of the site/mode's characteristics (catch rates) and costs, and across individuals for a given site as a function of the individuals' characteristics (location of residence, etc.). The expected compensating variation is then related to the more conventional deterministic compensating variation which is the amount the individual would pay to bring about a change in the characteristics or cost of a site/mode if he knew that he was going to choose that site/mode with certainty. The expected compensating variation derived from the random utility model is smaller than the deterministic compensating variation because of the uncertainty associated with the choice of site/modes.

FOOTNOTES

1. In terms of the option value literature, option value equals option price minus expected consumer's surplus. Therefore, if the individual is risk neutral option price equals the expected consumer's surplus. See Smith (1983) for a summary of the option value literature.

2. If additivity across trips is not assumed, the choice of a site/mode on a given trip would not be independent of the choice of site/mode on other trips and demand could only be estimated in a consistent utility theoretic manner if there was a complete record of where each individual went during the entire season.

3. Morey (1981) used a logit model to estimate the demand for Colorado ski areas. Caulkins, Bishop and Bouwes (1984) used one to estimate the demand for a number of lakes in Wisconsin. However, neither paper derives exact expected consumer surplus measures.

4. The more conventional assumption is that utility is always deterministic from the individual's perspective, but random from the investigator's perspective due to unobserved variables.

5. The standard logit model is defined here as a multinomial logit model that assumes the conditional indirect utility function has the linear form specified in (2a) and where the random component in (2a), ε_{jmti}, has an Extreme Value Distribution (4). This standard logit model should be contrasted with some of its recent generalizations. Logit models that assume ε_{jmti} has an Extreme Value Distribution are referred to as independent logit models (McFadden (1974)) whereas logit models that assume that ε_{jmti} has a Generalized Extreme Value Distribution are referred to as generalized logit models (McFadden (1978, 1981)). The standard logit model considered in this paper is therefore an

5. (Continued) independent logit model. Logit models can also be catagorized as to whether they admit income effects; that is, whether or not the discrete choice probabilities are a function of the consumers budget. Until recently, most logit models did not admit income effects. The standard logit model considered in this paper assumes no income effects. For more details see footnote 6 and Hanemann (1985) who considers expected consumer's surplus measures in the context of generalized logit models with income effects.

6. Most of the empirical logit literature assumes that the conditional indirect utility function (2) has this simple linear form. One could alternatively adopt the more general form

$$U_{jmti} = \beta_0 B_i - \beta_0 p_{jmi} + h_{jm}(a_{jm1}, a_{jm2}, \ldots, a_{jm5}) + \varepsilon_{jmti}$$

If one doesn't restrictively assume that $h_{jm}(a_{jm1}, a_{jm2}, \ldots, a_{jm5}) = \sum_{k=1}^{5} \beta_k a_{jmk}$, estimation is more difficult and many of the derived equations (e.g. (5), (6) and (8)) adopt more complex functional forms but the theoretical results remain effectively the same. The critical factor is that this more general specification maintains the standard logit assumption that the choice of alternatives is independent of B_i.

7. All consumer surplus measures are a positive function of the assumed value of time. The value of time is typically assumed to be between 20% and 50% of the manufacturing wage rate; $3.35 is approximately 40% of the manufacturing wage. For a survey of the empirical literature on the value of time see Cesario (1976).

8. The catch rate for species k at site j is the average catch rate for species k at site j for all individuals in the sample who visited site j. For more details see Rowe et al (1985).

9. The specific program used is the unconstrained Non-Linear Optimizaton Solver (Dennis and Schnabel (1983)). Ameniya (1981) has shown that the log of the likelihood function for the standard logit model is globally concave which implies that it has only a single global maximum. One therefore does not have to worry about the algorithm converging to a local maximum which is not the global maximum.

10. The CV_i could also be interpreted as our expectation of the amount individual i would pay on the morning of the trip to bring about the change. On the morning of the trip, v_i is deterministic from the individual's perspective so individual i knows exactly how much he would pay to face the choice set $(P_i'$, A'); for example, the individual will pay nothing if the change only improves a site that is not chosen. However, since v **i** is a random variable from our perspective we don't know the exact amount individual i will pay on the morning of the trip and we can only determine how much the representative individual will pay (CV_i). This latter interpretation of the CV_i is the more conventional interpretation but in the model presented here both interpretations are correct (see footnote 4).

11. A number of things about the CV_c's (8) should be noted. Hanemann (1985) shows that the CV_c's derived from the standard logit model (8) are invariant to monotonic transformations of the conditional indirect utility function (2a). This result depends critically on the standard logit assumption of no income effects. Therefore, the derived CV_c's (8) do not imply cardinal preferences and care must be taken so as to not inappropriately attach meaning to the cardinal properties of these expected compensating variations. For more details see Morey (1984). The absence of income effects also allows us to

11. (Continued) relate the CV_c (and EV_c) to an area under an expected Marshallian demand curve. This is the random utility analog to the deterministic result that the Marshallian and Hicksian demand functions coincide when there are no income effects. For example, if the cost of site j mode m decreases the CV_c (and EV_c) for that change is the area under site j mode m's expected Marshallian demand curve between the two cost levels. For more details see Hanemann (1985).

12. Feenberg and Mills (1980) derive a measure that is equivalent to the deterministic compensating variation measure defined in (16) and use it to estimate the benefits of an improvement in a site's water quality.

13. The exact formula is

$$CV_i(jm) = \sum_{\substack{\ell=1 \\ \text{except when } j=1 \\ \text{and } m=s}}^{J} \sum_{s=1}^{M} \int_{A_t(jm/\ell s)} DCV_{it}(jm/\ell s)\, f_\varepsilon(\varepsilon_{it})\, d\varepsilon$$

where

$$A_t(jm/\ell s) = \left\{ \varepsilon \,\middle|\, u^\circ_{nuti} \le u^\circ_{\ell sti} \le u^\circ_{jmti} \text{ and } u^\circ_{jmti} \le u'_{\ell sti} \text{ for } nu \ne \ell s \ne jm \right\}$$

The set $A_t(jm/\ell s)$ is that part of the joint density function of ε that implies site j mode m will be chosen with certainty on trip t before it is eliminated and that site ℓ mode s will be chosen with certainty after it is eliminated. The approximation (21) is obtained by ignoring the random components in the $DCV_{it}(jm/\ell s)$'s.

14. As noted earlier, Feenberg and Mills (1980) estimate a discrete choice random utility model but then calculate benefits using deterministic compensating variations. In the continuous choice literature, a non-random utility

14. (Continued) function is usually assumed and one then adds a random component on to the derived demand functions in an ad hoc manner. Consumer's surplus measures are then calculated maintaining the implicit assumption that the estimated utility function is still deterministic. Morey (1985) provides one of many examples.

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TABLE 1

Cost Per Trip to Each Site/Mode in Oregon from Five Representative Counties in Coastal and Central Oregon*

From/To	Curry	Coos	Douglass	Lane	Lincoln	Tilamook	Clatsop
Curry	1.96	28.97	41.89	50.11	89.80	116.82	161.97
Douglass	79.23	32.50	28.19	50.51	87.84	115.64	124.25
Clatsop	161.59	112.90	99.98	91.76	52.07	25.45	1.96
Multnomah (Portland)	167.46	118.77	95.67	84.71	50.90	29.75	37.19
Deschutes (Central)	136.78	105.46	94.89	86.67	93.32	116.42	125.03

*The costs reported in this table include travel costs and the opportunity cost of the individual's time in transit but do not include the on-site/mode costs. The average on-site/mode costs are $2.87 for beach and bank, $3.87 for man-made, $52.80 for charter boat and $22.83 for private boat.

TABLE 2

Catch Rates for Oregon
(average number of fish per day-trip)

	Mode*	Curry	Coos	Douglass	Lane	Lincoln	Tilamook	Clatsop
Salmon	MM	.03	.51	0	0	.01	0	.03
	BB	.16	.06	.08	0	.01	.04	0
	CB	.49	1.21	1.28	1.28	.60	.40	1.27
	PB	.41	.85	1.02	1.02	.51	.37	.70
Perch	MM	3.22	3.15	2.57	2.92	.77	1.15	1.27
	BB	1.00	4.97	2.83	1.00	2.88	1.24	2.87
	CB	0	0	0	0	0	0	0
	PB	0	.56	0	0	.60	.01	0
Smelt and Grunion	MM	.84	.76	.04	0	.01	0	0
	BB	0	.52	1.39	0	.91	0	0
	CB	0	0	0	0	0	0	0
	PB	0	.02	0	0	0	0	0
Flatfish	MM	0	.01	.08	.01	.05	0	.16
	BB	0	.06	.06	0	.11	0	.85
	CB	0	0	0	0	0	.02	0
	PB	0	0	0	0	.41	.01	0
Rockfish/ Bottomfish	MM	.02	1.40	1.29	4.72	1.00	.69	.46
	BB	.33	.94	1.98	.80	1.71	.28	1.43
	CB	0	6.85	0	0	5.15	.45	0
	PB	3.15	1.45	1.00	0	1.35	.31	0

*MM = Man-made structure, BB = Beach and Bank, CB = Charter Boat, PB = Private Boat

TABLE 3

Maximum Likelihood Parameter Estimates

	$-\beta_o$ Price	β_1 Salmon	β_2 Perch	β_3 Smelt and Grunion	β_4 Flatfish	β_5 Rockfish/ Bottomfish	Log of the Likelihood Function
Random Allocation across Site/Modes							-19,506
Costs Only	-.0550						-14,645
Costs and Catch Rates	-.0681	.9770	-.2605	.3621	.6079	.2346	-14,084

TABLE 4

The Estimated Probability that an Individual from County c Will Visit Site j Mode m on a Given Trip for Five Representative Counties in Coastal and Central Oregon
(rounded to nearest percent)

From/To	Mode*	Curry	Coos	Douglass	Lane	Lincoln	Tilamook	Clatsop
Curry	MM	.18	.06	.01	.02	0	0	0
	BB	.31	.02	.03	.01	0	0	0
	CB	.02	.03	0	0	0	0	0
	PB	.25	.04	.02	.01	0	0	0
Douglass	MM	0	.15	.11	.05	0	0	0
	BB	.01	.06	.23	.03	0	0	0
	CB	0	.07	.02	0	0	0	0
	PB	0	.09	.14	.03	0	0	0
Clatsop	MM	0	0	0	0	.01	.05	.27
	BB	0	0	0	0	.01	.05	.36
	CB	0	0	0	0	0	0	.04
	PB	0	0	0	0	.01	.03	.16
Multnomah (Portland)	MM	0	0	0	.01	.05	.18	.12
	BB	0	0	0	.01	.06	.18	.15
	CB	0	0	0	0	.01	.01	.02
	PB	0	0	0	0	.03	.09	.07
Deschutes (Central)	MM	0	.04	.05	.17	.08	.01	.01
	BB	0	.02	.10	.12	.08	.01	.01
	CB	0	.02	.01	.02	.02	0	0
	PB	0	.02	.06	.09	.05	.01	.01

*MM = Man-made structures, BB = Beach and Bank, CB = Charter Boat, PB = Private Boat

TABLE 5

The Estimated Per-trip CV_c's Associated with the Elimination of On-shore Fishing (S), Off-shore Fishing (B) and All Fishing (A) at Three Macro Sites (Clatsop, Douglass and Curry) for Individuals from Seven Representative Counties of Origin (rounded to the nearest cent)

At/From	Mode	Clatsop	Tilamook	Lincoln	Douglass	Curry	Multnomah (Portland)	Deschutes (Central)
Clatsop	S	14.60	1.83	.19	.01	0	4.55	.26
	B	3.29	.56	.06	0	0	1.30	.08
	A	26.08	2.47	.25	.01	0	6.35	.35
Douglass	S	.01	.25	1.07	6.19	.65	.08	2.37
	B	.01	.12	.50	2.61	.31	.04	1.08
	A	.02	.37	1.61	10.38	.97	.12	3.64
Curry	S	0	0	.01	.12	9.66	0	.09
	B	0	0	.01	.06	4.58	0	.05
	A	0	0	.02	.18	20.36	0	.15

TABLE 6

The Estimated Per-trip CV_c's Associated with the Elimination of Salmon Fishing in Clatsop County for Individuals from Seven Representative Counties of Origin (rounded to the nearest cent)

Clatsop	Tilamook	Lincoln	Douglass	Curry	Multnomah (Portland)	Deschutes (Central)
1.80	.32	.04	0	0	.73	.05

TABLE 7

The Estimated Per-trip CV_c's Associated with a Salmon Enhancement Program in Clatsop County (increasing each of the off-shore salmon catch rates by one) for Individuals from Seven Representative Counties of Origin (rounded to the nearest cent)*

Clatsop	Tilamook	Lincoln	Douglass	Curry	Multnomah (Portland)	Deschutes (Central)
-4.22	-.88	-.10	0	0	-1.93	-.14

*The CV_c's are negative indicating the amount the individuals would pay to bring about the change.

THE VARYING PARAMETER MODEL: IN PERSPECTIVE

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ABSTRACT

This paper describes the use of the varying parameter model for valuing an improvement in a characteristic (water quality) of a recreation site. This model is a multisite model that relates variations in the travel cost demand parameters to differences in site characteristics. The paper discusses the implicit assumptions and data requirements of the model and compares them to other recent models. It also demonstrates the importance of model estimation with truncated dependent variables. The paper presents benefits estimates for water quality changes at 22 recreation sites and compares these with other recent estimates.

I. INTRODUCTION

In their relatively brief history, environmental and resource economists have devoted considerable attention to determining the value of nonmarketed goods. Spurred by the need for valuation information to assist in recreation management planning, these economists have developed several models for deriving this information. Chief among these models is the travel cost model, which draws from the rich legacy of Clawson [1959] and Clawson and Knetsch [1966]. With its origins in trying to value the services of a recreation site, this approach uses travel distance and related costs as the implicit "price" that recreationists are willing to pay for using the services of recreation sites.

Many of the empirical applications of the travel cost model have measured either the value of an entire recreation site (see Dwyer, Kelly, and Bowes [1977], Loomis and Sorg [1982], and Bockstael, Hanemann, and Strand [1984]) or the value of using some part of a large resource like a national forest for recreation. More recently, recreation research in support of planning needs has shifted to more subtle types of valuation questions--the value of incremental changes, such as additional hiking trails or campgrounds, in the quality of existing resources. These questions emphasize the need for valuing a change in the quality of the services provided by the site. The policy evaluation requirements of the U.S. Environmental Protection Agency (EPA) has further emphasized the importance of this new direction in recreation research. For example, in accordance with Executive Order 12291, EPA must measure the benefits of water quality changes for all major regulations. In effect, therefore, given a major regulation affecting a water body such as a river, EPA must estimate the value of a quality change in one of its characteristics--water quality.

Not surprisingly, several recent studies have focused on measuring quality changes (e.g. , see Brown and Mendelsohn [1984], Morey [1981, 1984, forthcoming], Vaughan and Russell [1982a], and Smith, Desvousges, and McGivney [1983a,b]). Following the insights of the hedonic literature, these studies view quality changes as changes in the levels of the attributes or characteristics of recreation sites. Each has taken a different tack in the course of modeling how changes in these attributes affect recreationists' choices.

This paper has two objectives. Our first is to profile the varying parameter model used by Vaughan and Russell [1982a] and ourselves to value water quality changes. The essence of this model is that differences in characteristics among recreation sites will be reflected in the travel cost demand equations for these sites. In our profile of this model, we will describe briefly its key features, implicit assumptions, and data requirements. We also will highlight some of the issues in using the model to value water quality changes at a recreation site.

Our second objective is to provide some perspective on the varying parameter model by placing it in the context of the other recent studies that value quality changes. To provide this perspective, we will compare the varying parameter model to the models used in these studies. In addition, we will contrast our application of the varying parameter model with that of Vaughan and Russell [1982a].

Section II of this paper provides some background on the valuation issues covered in these recent papers. Section III highlights key features and assumptions of the varying parameter model. Section IV discusses the data requirements for the varying parameter model, along with those of the other approaches. Section V illustrates how we used the model to value water quality changes at 22 recreation sites. Section VI provides some implications for future research. Section VII lists references cited in this paper.

II. BACKGROUND

Several themes are common to the recent papers by Morey [1984, forthcoming], Vaughan and Russell [1982a], and Brown and Mendelsohn [1984]. One is the use of indirect methods in attempts to value quality changes. That is, by employing either behavioral or technical assumptions about household behavior, they all relate the demand for a nonmarketed good, or characteristic, to the observed demand for a marketed good. In keeping the focus of this paper within the confines of the variants of the indirect approach used in these papers, we are ignoring the contingent valuation studies that use a survey-based approach to directly elicit households' values for these quality changes. [1]

Another important theme appearing in varying degrees in each of these papers is the role of a recreation site's characteristics in reflecting quality changes. For example, Figure 1 shows that our varying parameter model views the demand for a recreation site's services as a function of its characteristics. A water quality improvement from WQ1 to WQ2 in Figure 1 causes an increase in the demand for visits to the site at every implicit price or travel cost. Our model considers the influence of quality changes from a quantity or visits perspective. Visits to sites with

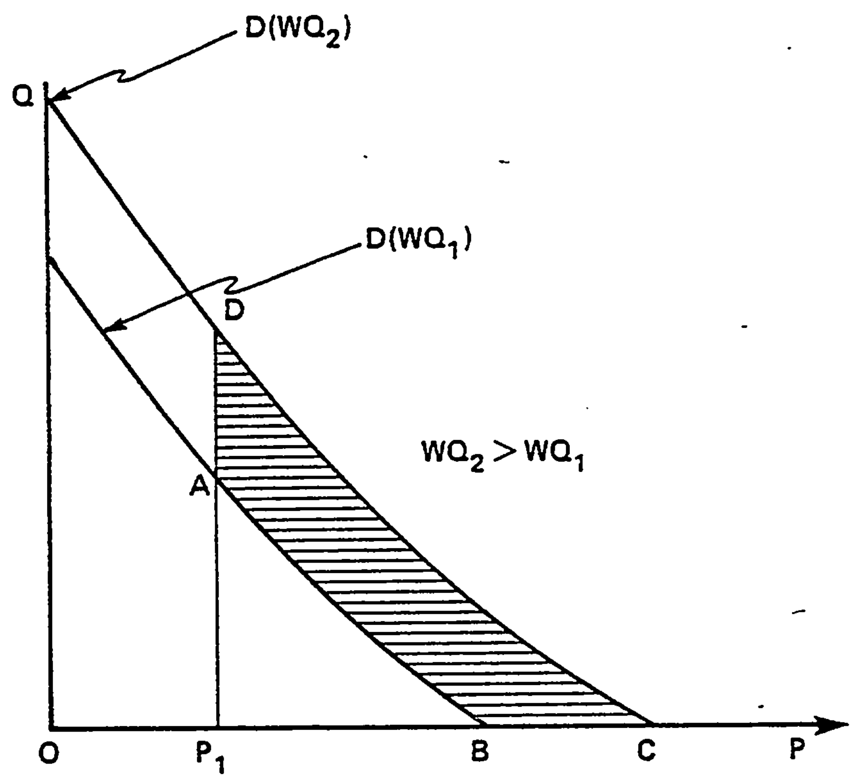

Figure 1. Travel cost demand function with water quality improvement.

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[1]It also is important to note that a survey-based data collection effort underlies each of the studies mentioned above. The main difference between these surveys is that individuals were asked to recall recreation experiences during a season and not directly asked to value the quality changes. However, there is nothing to prevent a survey from asking <u>both</u> types of questions. For example, the National Hunting, Fishing, and Wildlife survey asks both types of questions. We also asked both questions in Desvousges, Smith, and McGivney [1983] and found them to be excellent complements.

different levels of water quality will differ in their quality. Although we cannot measure the quality differences among visits of different sites, we assume that the parameters of a travel cost demand equation are functions of the site characteristics. This assumption enables us to value the change in quality of any characteristic by linking it to a change in the demand for the site's services.

The Brown and Mendelsohn [1984] also emphasizes the importance of site characteristics. However, they view the problem of valuing quality changes as a price index problem. In their model, consumers minimize the cost of producing each combination of recreation site characteristics. They estimate a price index by regressing travel cost for a given origin zone to each site on the vector of characteristics provided by each site. Repeating this process for each origin zone defines a modified "recreation hedonic price function" for each zone. By taking the partial derivative of each function with respect to a characteristic (e.g., water quality), they obtain the marginal implicit price of the characteristic. Performing the same task for other characteristics and using the features of each origin zone's population, they estimate the demand for all the recreation site's characteristics.

Morey's [1984, forthcoming] approach places even greater emphasis on the role of characteristics in valuing quality changes. Focusing on the demand for an activity instead of on that for a site, Morey incorporates the physical characteristics of activities and personal characteristics of an individual into an expenditure function. He uses this function to define welfare measures for changes in either the cost or physical characteristics of the activities.[2]

Finally, all these studies use data from visits to multiple sites to implement their models. For example, Vaughan and Russell [1982a] use information from a sample of fee fisheries for their varying parameter model, while we use data from 22 Corps of Engineers general purpose, flatwater recreation sites and Morey [1984 forthcoming] estimates his model for fifteen Colorado ski sites. Brown and Mendelsohn [1984] have the largest universe of sites, with information on steelhead fishing at over 140 different rivers in Washington. The multiple site orientation reflects a shift in direction away from the single-site orientation of the majority of the early travel cost studies. This shift is due primarily to the emphasis on valuing quality changes in a site's characteristics which requires variation across sites for implementing any of the models.

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[2]Morey [forthcoming] argues that when characteristics of an activity are included in a demand function, the activity's name is unnecessary to explain the demand for that activity. That is, only the characteristics are important. On a substantive level, this view ignores the possible importance of "context" effects that influence consumer behavior. For example, Schoemaker [1980] showed respondents evaluating the same gambles differently in the context of a lottery rather than insurance.

III. THE MODEL

To highlight our interpretation of the varying parameter model, we adopt the household production framework. For simplicity, we assume that the household consumes two final service flows or basic commodities--a recreational activity, Zr, and a nonrecreation composite service, Zn.[3] By combining time, market purchased goods, and the services of a recreation site, the household is assumed to produce a recreation service flow (e.g., swimming or fishing). For a recreation season, the price of fishing at the recreation site is the implicit time, travel, and other incremental costs incurred in visiting the site. Visits to a site during a season are the corresponding measure of the quantity of the site's services demanded by the household.[4]

The household's objective function can be viewed as maximizing the utility derived from these activities, subject to a "full" income constraint (i.e., a constraint combining the budget and time restrictions facing the household) and the production functions for the final services flows.[5] The two most important components of this objective function for our application are the budget constraint and the household production function for recreation services. The first of these is given in Equation (1):

$$Y = wt_w + R + L = P_{n+1} X_{n+1} + \sum_{i=1}^{n} P_i X_i + (Td_1 + ct_1 + w_0 t_{v1})V_1 + (Td_2 + ct_2 + w_0 t_{v2})V_2 \ , \quad (1)$$

where

Y = full income (i.e., including wage income, wt_w, nonwage income, R, and foregone income, L)

w = market wage rate

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[3]The terms household and individual will be used synonymously. (For the specific underlying assumptions see Becker [1974].)

[4]Bockstael, Hanemann, and Strand [1984] point out that this is a key simplification of the household's decision process. They suggest that households engage in a two-tiered decision process. First, it decides to fish or swim and then chooses the site at which this activity will occur. Unfortunately, the data precluded our ability to analyze this decision process because it contained a household's seasonal visits to a particular site. This feature of the data poses other difficulties; these are discussed in the next section.

[5]For discussion of the household production framework in general terms, see Pollak and Wachter [1975]. Deyak and Smith [1978] and Bockstael and McConnell [1981] consider the implications of the framework for recreation models.

t_w = work time

X_i = ith market goods used in production of the nonrecreational service flow (i = 1, 2,...,n)

P_i = price of ith good (i = 1,2,...,n+1)

X_{n+1} = market good used in production of recreation service flow

T = vehicle related travel cost per mile

d_j = round-trip distance to jth site (j = 1,2)

c = individual's opportunity cost of travel time to a site

t_j = round-trip travel time to jth site (j = 1,2)

w_0 = opportunity cost for time onsite

t_{vj} = time onsite per trip to jth site (j = 1,2)

V_j = number of trips to jth site in specified time horizon.

This formation of the consumer choice problem embodies several implicit assumptions. For ease of exposition, we assume that the individual considers the use of only two different sites. The time onsite is assumed to be constant across all trips to each site, implying that the implicit prices to the individual for a change in either the time onsite per trip or the number of trips will be interrelated.[6]

Finally, our statement of the budget constraint allows for a general treatment of the opportunity cost of time. However, in practice we have used the wage rate as a proxy for the value of the household time. As Bockstael, Hanemann, and Strand [1984] point out, the wage rate is the relevant measure of opportunity cost only to the extent that households can adjust their marginal hours worked at its wage rate. In addition, the household may face constraints on when and how their available time occurs. That is, they may be required to work only 40 hours a week or 50 weeks a year. In effect, some households may be unable to adjust the number of hours worked or may be able to do so only by moonlighting at a lower wage rate. While the more complete view of time costs by Bockstael, Hanemann, and Strand [1984] is consistent with our model, it is precluded by the available data.

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[6]This specification also implies that the choice of trips to the site and time onsite are jointly determined. Thus, if onsite time costs are included in the implicit price of a trip, a simultaneous equations estimator must be considered. Further details are developed in the third section of this paper.

The alternative treatments of time costs across the recent studies does provide some useful perspective, however. For example, with data available only on their recreation sites and not users, Vaughan and Russell [1982a] used the two extreme values for time costs--zero and the full wage rate--and evaluated the sensitivity of their results to these extremes. Brown and Mendelsohn [1984] used income as a proxy for the wage rate, examined the robustness of demand regressions using different percentages of the wage rate, and presented results for time valued at 30 percent of the proxy wage rate. Morey [1984, forthcoming] uses the minimum wage for his sample of college student skiers.

The picture that emerges from all the studies is the inadequate treatment of the opportunity cost of time in recreational demand models. While Bockstael, Hanemann, and Strand [1984] have clarified some important aspects of this thorny problem, the confusion continues. The biggest single problem stems from analysts forgetting that opportunity cost is the relevant measure of all costs. Simply because travel time in scenic areas is enjoyable does not mean we ignore the full opportunity cost of that travel time. This remains an important area for future research.

To consider the appropriate treatment of site characteristics in a recreational demand model requires us to specify their role in household production activities. Equation (2) provides a general statement of the production function for a recreation activity (fishing), with a_j designating the vector of attributes for site j:

$$Z_r = f_r(X_{n+1}, V_j, t_{vj}, a_j) \quad (2)$$

For this two-site example (i.e., j = 1,2), this formulation assumes that either site can contribute to the production of Z_r, with the relative productivity of each site determined by its characteristics. Assuming $f_r(.)$ is strictly monotonically increasing in all arguments, we can derive a conversion function for site services (holding t_{vj} equal for j = 1 and 2) as the ratio of the visit requirement functions for the two sites at the same level, of output and other inputs (i.e., solving (2) for V_j in terms of its arguments for j = 1,2). This function enables us to convert measures of visits to sites with different characteristics into a single measure of the use of all sites.

In general terms, our production function implies that the conversion function depends on the level of output, Z_r, a variable not easily measured. However, following Lau's [1982] analysis, we can assume that this input conversion function is independent of the level of the activity produced, implying that the production function must have an augmentation form (i.e., $Z_r = f_r(X_{n+1}), H(a_j)V_j, t_{vj})$, where $H(a_j)$ = augmentation function). In other words, our conversion function reflects the contribution of each attribute to the relative productivity of each site. For example, improved water quality would enhance the productivity of a site in providing fishing or swimming. Nevertheless, our conversion function does implicitly assume that only site characteristics will determine the substitutability between sites. In this view, the conversion function is used to adjust for differences in characteristics between two sites, the two sites would be perfect substitutes.

The assumptions of nonjointness and homotheticity in household production activities involving recreation sites, together with the augmentation format for the contribution of site characteristics, permit a direct interpretation of the travel cost demand model. More specifically, the household's cost function for the recreational service flow can be written as Equation (3) below:

$$TC = g(Z_r) \cdot G(P_{n+1}, w_0, h_j/H(a_j)) \ , \quad (3)$$

where

$h_j = Td_j + ct_j.$

The demand for a site's services will be given as:

$$\partial TC/\partial h_j = 1/H(a_j) \cdot g(Z_r) \cdot G_3(P_{n+1}, w_0, h_j/H(a_j)) \ , \quad (4)$$

where

$G_3(\cdot)$ = the partial derivative of $G(\cdot)$ with respect to its third argument.

Thus, the travel cost demand model can be interpreted as the derived demand for a site's services associated with the production of recreational services. This derived demand function will be related to Z_r, P_{n+1}, the implicit price, h_j, and $H(a_j)$. Moreover, when the model is specified with trips as a function of travel costs, income, and other socioeconomic variables describing the features of the individual, it implicitly assumes X_{n+1} is given and that the optimal Z_r can be expressed as a function of income and the travel costs (and not the "prices" of other final service flows such as Z_n in our case). Finally, since site attributes will determine the productivity of a unit of a site's services, the parameters of each travel cost demand function should all be a function of site characteristics, as given in Equation (5) below.[7]

$$\begin{aligned} \ln V_{jm} = {} & b_0(a_{1j}, a_{2j}, \ldots, a_{kj}) + b_1(a_{1j}, a_{2j}, \ldots, a_{kj}) h_{jm} \\ & + b_2(a_{1j}, a_{2j}, \ldots, a_{kj}) \ Y_m + \Sigma \ \beta_s(a_{1j}, a_{2j}, \ldots) Z_{sm} + \varepsilon_{jm} \ , \end{aligned} \quad (5)$$

where

Y_m = family income for mth individual as a proxy for full income

Z_{sm} = sth socioeconomic characteristic for the mth individual.

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[7]Brown and Mendelsohn [1980] have approached the same type of problem and utilized a hedonic travel cost framework to describe behavior. The theory underlying their model parallels our analysis. However, their framework leads to models capable of deriving the demand for an attribute of a site rather than the demand for a site with specific attributes.

With the main features of our conceptual foundation developed, the key assumptions merit some additional discussion. One of the most crucial assumptions is the ability of our conversion function to reflect the influence of substitute sites. That is, we assume that the differences in site attributes are capable of reflecting all aspects of substitution opportunities. Although a site's characteristics are likely to have an important influence on substitutability among sites, our model ignores the effect of different prices for obtaining the site attributes. For example, a fisherman would consider the time and travel costs for a site as well as its water quality. This limited role for substitution opportunities reflects the inadequacy of our data set rather than an inherent deficiency of the varying parameter model. We were unable to identify the alternative sites our sample of recreationists visited during the season.

The assumptions of nonjointness and homotheticity in the households' recreation production are also important. Extending our earlier fishing example, homotheticity implies that a fisherman's marginal rate of technical substitution between labor (or time) and capital remains constant as the rate of fishing activity increases (along a ray from the origin). Clearly, this is a simplification because it is likely that a fisherman would substitute more capital--a bigger boat or motor or more sophisticated electronics--for his time or labor input--when he increases his rate of fishing. By assuming hometheticity we are not allowing these kinds of adjustments in production, which could cause us to overstate the cost of producing the fishing activity.

Nonjointness is also a simplification that is unlikely to be reflected in the "real world" of recreation activities. For example, it is a relatively simple matter for a fisherman to spend time camping, picnicking, swimming, or just boating during a fishing trip to a recreation site. By attributing all the costs to the production of fishing, we are misspecifying our travel cost model by overstating the cost of fishing.[8]

How do these assumptions compare with those required to implement the models from other recent studies? Table 1 highlights the key assumptions that are employed in other recent recreation models. For example, the Vaughan-Russell [1982a] version of the varying parameter model assumes that the type of fish species available at a recreation site is the site characteristic that reflects a change in water quality. This view leads them to estimate separate travel cost demand equations for each species. The crucial question is how well available fish species reflects water quality changes. This is probably suitable for fishing--Vaughan and Russell's main objective--but it does not address how water quality changes affect other activities.

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[8]In Desvousges and Smith [1984] we have examined the role that activities play in our conceptual component of the varying parameter travel cost model. We suggest that the relevant question is, "How do you add up the various individual demands for a site's services when different types of activities are undertaken?" Unfortunately, the available data were not up to the empirical tasks that we demanded of it for this aggregation question.

TABLE 1. IMPLICIT ASSUMPTIONS

Author	Assumption
Vaughan-Russell [1982a]	Species type is most important site attribute for valuing water quality changes.
Brown-Mendelsohn [1984]	Hedonic price function serves some purpose as in conventional hedonic. Hedonic price function in linear.
Morey [forthcoming]	Activity is weakly separable. Nonjointness in production. Homothetic demand functions. All characteristics are specified.

In addition, Vaughan and Russell do not explicitly address the interrelationships between demands for different species. Are these important considerations for a household? For example, does it decide between visiting a catfish site and a trout site? One could imagine that other site characteristics (e.g. , scenic beauty) would influence the choice of a site and that these characteristics might affect catfish sites differently than trout sites. In summary, the Vaughan-Russell model seems plausible for the specific purpose for which it was intended, but it would require considerable modification to make it a more general purpose model.

Brown and Mendelsohn [1984] make three important assumptions in implementing their hedonic travel cost model. First, they assume that their hedonic price function plays a role similar to that of other such functions (e. g. , housing markets). Using their example, the steel head fisherman is a price taker who responds to the hedonic price function that defines how the price of a fishing trip will change as the mix of site characteristics change. In the conventional hedonic model, this function is an equilibrium relationship that results from the actions of all demanders and suppliers of the commodity, steelhead fishing trips. Although it is relatively easy to see how individuals are allocated to different points along this function depending on their value for a characteristic in a housing market, it is not clear how this allocation is performed in steelhead fishing. In other words, how does this price function perform as the equilibrating mechanism for the steel head fishing market?

The second implicit assumption of the Brown and Mendelsohn model is that the hedonic price function is linear. The linear form implies that individuals can repackage site characteristics in any combination they choose. This assumption seems inappropriate for recreation sites that may have some characteristics that are difficult to alter. While it may be easy to alter fish density with a stocking or some other fish management program, it is more difficult to change the degree of crowdedness or scenic beauty at a recreation site.

Finally, the Brown and Mendelsohn model does not address the discrete nature of many recreation decisions. That is, they estimate hedonic price equations for a season rather than for a specific trip. Thus, we do not obtain any insight about the discrete choice that steelhead fishermen make between the relevant choice set of sites.

The Morey approach also requires several implicit assumptions before it can be employed to model recreation demand. For example, Morey [forthcoming] assumes that activities are not jointly produced--the same assumption we employed in our varying parameter model. This assumption has the same effect of overstating costs of an activity as in our application. Morey imposes an additional simplifying assumption that the households' ability to produce recreation activities exhibits constant returns to scale. Using Morey's skiing example, a doubling of inputs such as skiing time and equipment results in a doubling of skiing activity. Thus, Morey's view of activity production is similar to the simplistic character assumed in our varying parameter model. This reflects more an overall lack of understanding about recreation activities than an inherent flaw in either models.

To estimate his model, Morey assumes that his main activity of interest--skiing--is weakly separable from all other activities. This implies that consumer demand, and subsequent expenditures on skiing, are unaffected by other activities, such as relaxing in a mountain environment or driving for pleasure. If this separability assumption does not hold, the expenditure share model Morey estimates may be incorrectly specified.

A final implicit assumption in the Morey model is that all the relevant characteristics of an activity are specified in the individual's demand function. While this is a plausible assumption, it appears to be a difficult one to implement. For example, Morey includes four characteristics in his restrictive constant elasticity of substitution (CES) demand function[9] but is only able to include two characteristics in less restrictive generalized CES (GENCES) demand function because of the estimation requirements for the complex model. If Morey's model requires that all characteristics be included, there seems to be some inconsistency between two different forms of his model.[10]

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[9]The CES is restrictive in the sense that it assumes that the demand function is homothetic. This assumption implies that the demands for recreation activities all have unitary income elasticities. In effect, skiing becomes an essential good.

[10]The situation may be even more complicated because it appears that the two characteristics--total skiing area and skill-specific skiing area--included in the GENCES Model are interdependent. In fact, it seems that the quantity of skill-specific skiing area is a subset of the total area. Morey does not discuss the potential significance of reducing characteristics from four to two in his two model versions or the interrelationships between characteristics.

In summary, each of the recent multiple site models for valuing changes in a site attribute requires implausible assumptions about either the production of, or demand for, recreation activities. In almost all instances, the lack of realism in the assumptions can be traced to two causes--the inadequacy of our understanding of household's recreation behavior and the egregious quality of the available data. Our lack of understanding of household behavior is due in part to the distance economists generally keep from the subjects whose behavior they attempt to model. This distance also is reflected in our inattention to the types of data requirements of our revealed preference models, the focus of the next section of this paper.

IV. DATA

The Federal Estate component of the 1977 Nationwide Outdoor Recreation Survey conducted by the Department of the Interior provided the source for visitor information to estimate our travel cost models. The Federal Estate includes all federally owned lands with public outdoor recreation areas. A total of 13,729 interviews with recreationists were conducted at 155 sites during the time of the survey. We limited our analysis to 43 U.S. Army Corps of Engineers sites with consistent visitor data because they provided a fairly comparable range of water-based outdoor recreational activities. A separate data source, the Corps' Recreation Resource Management System, provided information on the site attributes, including a variety of measures of the facilities available and natural features of each site.[11] The National Water Data Exchange (NAWDEX) supervised by the U.S. Geological Survey was the source for the water quality data. To establish a linkage between the water quality monitoring stations and the sites, the latitude and longitude of stations and recreation sites were used. Monthly readings were collected for the months from June through September for 1977 and the years before and after the survey to supplement the 1977 information in cases of missing data. Nonetheless, only 33 of the 43 sites had sufficient information for the other site characteristics and the water quality parameters.[12]

The character of our data has an important implication for our estimation of the varying parameter model. Specifically, our data are from a

[11]The specific measures of site characteristics considered were total shoremiles; total site area; pool surface area; number of developed multipurpose recreational areas at the site; number of developed access areas on the site; number of picnic locations; number of developed camp locations, boat launching lanes, and private and community docks at the site; and the number of floating facilities at the site.

[12]Seven measures of water quality were collected, including dissolved oxygen, fecal coliform density, pH, biochemical oxygen demand, phosphates, turbidity, and total suspended solids. In addition, two indexes of water quality were also considered--the National Sanitation Foundation (NSF) index and the Resources for the Future (RFF) index developed by Vaughan [1981] and underlying the RFF water ladder.

survey of users conducted at each of the recreation sites. This type of survey is commonly used in recreation studies because it identifies users at a reasonable cost. However, it provides no information on individuals who chose not to use the site. This causes the measure of quantity demanded, the trips to a site for a season, to be truncated at one. In addition, the coding procedures used in the survey caused this variable to be censored for the highest levels of use. (The last trip interval was recorded as six or more trips.) Screening our sites to eliminate the ones most severely affected by these problems reduced our sample to 22 sites. Table 2 summarizes the characteristics of these sites and their users.[13]

To assess the representativeness of the data used in estimating our varying parameter model, we have evaluated them from both a demand and supply perspective.[14] While these kinds of comparisons can be treacherous, the objective was not to be precise. Rather, it was to make a general comparison in fairly crude terms that would serve to identify broad similarities or differences.

On the demand side, we compared the characteristics of the users of 43 Corps of Engineers sites with those of the general public and with those of the users of other Federal Estate lands. Compared to the general public, users of the Corps of Engineers sites are more likely to be younger, to be Caucasian, and to be employed as craftsmen or foremen. They also are more likely to live in rural areas, to have attained slightly higher levels of education, and to earn higher incomes. In comparison with users of other Federal Estate lands, users of the Corps of Engineers sites are less educated and are less likely to be employed professionals or technical workers. They also earn lower incomes, are more likely to live in rural areas, and are more likely to have visited a site closer to their residences. On the whole, the users of Corps sites are fairly typical of a broad spectrum of the population.

On the supply side, we compared activities supported by the Corps of Engineers sites with those supported by other water-based sites on State and Federal Estate lands. Generally, all the sites support a broad range of activities, with boating, fishing, swimming, picnicking, and camping the most popular. Differences seem to be most prevalent in less popular activities like horseback riding. The Corps of Engineers sites are representative of sites that support flatwater boating and fishing, as well as extensive camping. In summary, our Corps sites seem representative of a large share of water-based recreation sites.

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[13]In subsequent analysis we have taken two additional steps: we acquired missing characteristics data to help us estimate the model for all our sites, and we developed a maximum likelihood estimator to account for the truncated and censored dependent variable. Unfortunately, we found that our model performed best for the 22 sites. For more details, see Desvousges and Smith [1984].

[14]For more details see Desvousges and Smith [1984].

TABLE 2. THE CHARACTERISTICS OF THE SITES AND THE SURVEY RESPONDENTS SELECTED FROM THE FEDERAL ESTATE SURVEY

Project name	Site characteristics: Property code	Recreation days	Shore miles	Area acres	Predicted wage rate $\bar{X}$	Predicted wage rate σ	Household Income $\bar{X}$	Household Income σ	Visits $\bar{X}$	Visits σ	(T+M) Cost $\bar{X}$	(T+M) Cost σ	Miles[a] $\bar{X}$	Miles[a] σ	Number of observations[b]
Arkabutla Lake, MS	301	2,011,700	134	52,549	5.23	1.45	13,184	8,974	5.4	2.7	20.04	27.94	45	90	61
Lock & Dam No. 2 (Arkansas River Navigation System), AR	302	343,700	96	32,415	5.24	1.03	10,409	3,991	6.8	2.0	3.04	13.01	55	33	41
Belton Lake, TX	304	2,507,000	136	30,789	5.52	1.51	17,279	11,913	6.0	2.8	33.18	52.35	67	142	53
Benbrook Lake, TX	305	1,978,000	37	11,295	5.00	1.21	19,135	10,065	2.3	1.2	30.23	58.93	73	223	46
Blakely Mt. Dam, Lake Ouachita, AR	307	2,104,300	690	82,373	5.24	1.53	17,144	9,524	4.3	2.8	45.39	49.31	121	139	91
Canton Lake, OK	308	3,416,500	45	19,797	5.09	1.54	17,392	10,553	4.6	3.2	32.30	22.97	95	99	74
Cordell Hull Dam & Reservoir, TX	310	2,167,900	381	32,822	5.43	1.58	15,491	9,215	5.7	2.9	29.65	34.70	60	87	104
DeGray Lake, AR	311	1,659,700	207	31,800	5.17	1.58	19,235	10,612	4.8	2.7	42.04	43.42	115	164	49
Grapevine Lake, TX	314	5,139,100	60	17,828	5.20	1.58	19,309	10,992	6.3	2.6	38.45	64.32	92	217	92
Greers Ferry Lake, AR	315	4,407,000	276	45,548	5.15	1.45	15,890	8,562	4.7	3.0	54.16	70.00	154	306	217
Grenada Lake, MS	316	2,553,900	148	86,826	5.13	1.56	9,199	4,833	6.4	2.6	24.57	32.90	65	165	75
Hords Creek Lake, TX	317	359,500	11	3,027	5.26	1.42	16,263	9,699	4.4	3.0	39.46	48.25	108	170	54
Melvern Lake, KS	322	2,034,600	101	24,543	5.69	1.65	18,087	9,015	4.3	3.0	31.48	29.39	84	137	45
Millwood Lake, AR	323	2,042,300	65	142,100	5.49	1.87	18,630	1,319	5.6	3.0	37.62	55.21	90	176	53
Mississippi River Pool No. 6, MN	325	645,500	55	11,292	5.79	1.42	19,589	10,693	4.8	3.0	52.23	55.19	141	240	70
New Savannah Bluff Lock & Dam, GA	329	207,600	32	2,030	5.28	1.13	12,609	9,414	5.8	2.7	18.65	23.78	37	77	39
Ozark Lake, AR	331	1,102,000	173	39,251	5.02	1.22	12,654	7,568	4.9	3.0	58.71	98.54	199	433	52
Philpott Lake, VA	333	1,454,900	100	9,600	5.33	1.55	14,268	6,668	5.8	2.6	26.09	46.00	47	100	38
Proctor Lake, TX	337	975,200	27	15,956	5.49	1.63	17,510	11,167	5.4	2.9	46.08	40.96	109	103	52
Sam Rayburn Dam & Reservoir, TX	339	2,728,700	560	176,869	5.32	1.35	19,515	11,331	4.1	2.7	40.23	31.90	85	74	67
Sardis Lake, MS	340	2,488,900	110	98,590	5.41	1.31	13,141	7,223	6.5	2.3	36.08	42.17	123	234	205
Whitney Lake, TX	344	1,976,400	170	53,230	5.25	1.29	18,688	11,651	5.0	2.8	35.40	38.03	96	195	201

[a]One-way distance to the site.

[b]Number of observations are based on the final models estimated for site.

NOTES: $\bar{X}$ is the arithmetic mean.
σ is the standard deviation.
(T+M) cost is the sum of vehicle and time-related costs of a visit.

For perspective on the data requirements of our varying parameter model, we can compare them with the data used in the other recent studies. Table 3 summarizes the key features of the data used in each study including the type of survey, sample size, variable measurement, and the type of characteristics information. Several interesting points can be gleaned from this table. For example, the data from these studies are all drawn from populations of users. In effect, they do not yield information about households who have not chosen to engage in some type of outdoor recreation activity. As we noted earlier, this has important implications for the types of statistical estimation models. Bockstael, Hanemann, and Strand [1984] also point out that data sets based only on users do not allow for zero consumption of a recreation site's services (i.e., corner solutions are excluded).

In addition, the data contain no information on the discrete choices households make among sites when deciding on the one they are going to visit. Bockstael, Hanemann, and Strand [1984] suggest that this also is an important dimension of the recreation decision that is too frequently ignored in recreation demand models. Even the recreation participation surveys that include both users and nonusers (e.g., see Vaughan and Russell [1982b]) do not address the choice among sites. Generally, the focus of participation surveys is limited to the recreate/not to recreate choice and not to a profile of all choices during a season.

There also are some significant differences among the data from the studies summarized in Table 3. For example, Vaughan and Russell obtained visit and site data from the owner/operators of the recreational fee fisheries, while the other three studies had surveys of the users of these sites. The Vaughan and Russell survey approach assumes that owner/operators have accurate understanding of both their customers and their site characteristics. It is somewhat analogous to the key informant survey method that is popular in anthropological and organizational management research.

In addition, the Morey [forthcoming] data set has the most limited coverage of a population. It is limited to a subset of the skiing population--college student skiers. The Brown-Mendelsohn [1984] data have the largest coverage of one group of recreationists, containing interviews from 5,000 fishermen. Our data set has the most extensive coverage of recreationists engaged in a wide range of water-based recreation activities.

Finally, there are some subtle differences among the data on site characteristics among the various studies. The data used with the two varying parameter models have the most detailed, descriptive information of site characteristics. By contrast, the Morey and Brown-Mendelsohn data sets included only relatively few site characteristics--4 and 3 characteristics, respectively. Brown and Mendelsohn used perception-based measures, the mean values from respondents' ratings of each of the three characteristics for the 140 plus rivers in their study. Unfortunately, we have almost no information on the relative performance of different measures of the same characteristics to make a more definitive judgment of the most appropriate measure.

TABLE 3. PROFILE OF DATA USED IN RECENT RECREATION DEMAND MODELS

	Models			
	Varying parameter		Hedonic travel cost	Characteristics demand
Data features	Desvousges-Smith [1984]	Vaughan-Russell [1982]	Brown and Mendelsohn [1984]	Morey [forthcoming]
Sample size and composition	Personal interview survey of 1,781 visitors at 22 Corps of Engineers recreation sites across the United States.	Mail interview survey of owner-operators of 149 recreational fee fisheries across the United States.	Mail interview of 5,500 licensed fishermen in Washington.	Survey of 163 single college student skiers
Dependent variable	Visits per capita per season.	Owner-operator reported estimates of total visitors allocated by origin zone.	Miles and hours for visitors in 63 origin zones for over 140 rivers.	Expenditure shares sample individuals for 15 sites.
Travel cost and related expenditures	Separate estimates of travel tine, onsite time, used $0.08 variable cost for mileage, predicted wage for time cost.	One-way zone travel cost ($.076 per mile) plus fee or same plus travel time valued at BEA hourly wage rate for zone.	Travel costs at $0.10 or $0.20/mile and time at 30 percent, 60 percent and 100 percent wage rate; different models for different length trips.	Travel time cost at $1.15 minimum wage; lift ticket prices for each site; unspecified value for distance costs.
Sociodemographic variables	Standard variable list plus several attitudinal variables.	Average income and population for zone from new area file.	Income, fishing experience.	Skiing ability; family characteristics
Substitute site visits	Manager assessment of importance of substitutes.	Owner-operator assessment of degree of competition.	Number of trips to each site and average length of trip.	Number of trips to each site and length of visit.
Site characteristics	Corps estimates of access, area, pool size. fish species; facilities; site manager's assessment of congestion levels.	Access, area size, surrounding countryside, congestion, fish species provided by owner/operator.	Mean value of respondents' assessments of congestion, scenic beauty, and fish density.	Estimates of acres of ski runs, acres of specifically designed ski runs, vertical transport feet, and average snow fall.
Activities	List of all activities on "surveyed" visit but no allocation of time spent on different activities.	Type and number of fish caught.	Steelhead fishing	Downhill skiing

What are the lasting impressions that we take from reviewing these data? Clearly, none of the data sets is ideal. All involve compromises. Most were collected for purposes other than the one for which they were used in these studies. Thus, many questions that would be relevant to recreation demand models were omitted from the surveys in favor of ones that fulfill other objectives. As noted earlier, the treatment of the opportunity cost of time is inadequate in all the surveys.

One impression still nags at us. This impression stems from the analysts who view contingent valuation and revealed preference models reviewed in this paper as competitors. In our view, they are better complements than substitutes. For example, the types of information needed to deal with the data problems for the models discussed in this paper could be included in a contingent valuation survey effort. If the attention frequently devoted to questionnaire development in contingent valuation were spent on designing data for indirect methods, the ability of our models to perform would improve substantially.[15] Yet these issues will remain unresolved unless there is funding for basic research on recreation demand models and subsequent primary data collection.

V. ESTIMATION AND RESULTS

In this section we briefly review our estimation procedures for the generalized travel cost model. In addition, we provide some summary results on the benefits of improving site characteristic--water quality--based on our model. Both the procedures and results are based on additional research over the last 2 years and differ significantly from those presented in Desvousges, Smith, and McGivney [1983].

The major focus of our revised model is to address the estimation problems created by the censored and truncated nature of our dependent variable. As noted earlier, this character of our variable visits is attributable to the onsite data collection that included only users, along with the coding procedure used by the interviewers for the maximum number of visits. To address these problems, we have reestimated each demand function with a maximum likelihood (ML) estimator that takes account of the truncation in visits at low levels of use and the censoring in the upper levels of use. Under the assumption of a normal error structure, with truncation at zero[16] and censoring at k, the likelihood function is given in Equation (6):

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[15]The complimentarity between contingent valuation and the revealed preference models is a two way street. For example, practitioners of contingent valuation would benefit substantially from the kind of model development that goes hand in hand with revealed preference approaches. Smith [1985] and Hanemann [1984] imply that contingent valuation will never fully mature unless it can develop models of how respondents answer the valuation questions.

[16]The truncation at zero arises because the dependent variable for the demand function was the logarithm of visits.

$$L(\bar{\beta}, \sigma^2, \overline{\ln V}) = \prod_{i\varepsilon S_1} \frac{\frac{1}{\sigma}\phi(\ln V_i - \overline{\beta X}_i)/\sigma)}{(1-\Phi(-\overline{\beta X}_i/\sigma))} \prod_{i\varepsilon S_2} \frac{1-\Phi((k-\overline{\beta X}_i)/\sigma}{(1-\Phi(-\overline{\beta X}_i/\sigma))}, \quad (6)$$

where

$\ln V_i$ = natural log of the number of visits to the site by the ith individual

$\bar{\beta}$ = paramter vector (1 x k)

$\bar{X}_i$ = vector of independent variables describing ith individual (k x 1)

σ^2 = variance in the error associated with each site's demand function

S_1 = set of observations with $0 \leq \ln V_i < k$

S_2 = set of observations with $\ln V_i \geq k$

$\phi(\cdot)$ = density function for the standard normal variate

$\Phi(\cdot)$ = Distribution function for the standard normal variate

Table 3 reports the demand estimates from our earlier research in Desvousges, Smith, and McGivney [1983] and Smith, Desvousges, and McGivney [1983b] using OLS and the maximum likelihood methods for each of the 22 sites used in the development of our original model. (We employed the Davidon-Fletcher-Powell [1963] algorithm in GQOPT to obtain the ML estimates.) The model is consistent with our first version of both the site demand functions and the second stage, demand parameter-site characteristics models. That is, we specified quantity demanded (the natural log of visits) to be a function of travel costs (including round trip vehicle related costs and the time costs of travel) and the household income. Generally, the ML results differ substantially from the original OLS estimates. For example, the ML estimates of the travel cost parameter are larger in absolute magnitude, which implies more elastic site demands.

Also noteworthy is that the coefficients of models for the 22 sites we had earlier judged less likely to be affected by the truncation and censoring problems changed substantially. When we estimated the model for the complete universe of our sites with the ML estimator, the smaller sample results were consistently more plausible. Thus, we found the truncation/censoring effects to have sizable effects on the coefficients of our first stage travel cost demand models.

Table 4 reports the generalized least-squares estimates for the second stage demand parameters using the ML estimates. While the specification corresponds to what was used in the first generation framework, there are

TABLE 4. MAXIMUM LIKELIHOOD AND OLS ESTIMATES OF GENERAL MODEL BY SITE
LN VISITS $\alpha_0 + \alpha_1$ (T+M) COSTS + α_2 INCOME

Site name	Site No.	Estimator	Intercept	T+M cost	Income	Function value	R^2	df
Arkabutla, Lake, MS	301	ML	2.33 (8.21)	-0.0473 (-6.20)	1.9×10^{-6} (0.11)	-24.00	-	-
		OLS	1.58 (9.99)	-0.0093 (-3.09)	6.2×10^{-6} (0.67)	-	0.15	58
Lock and Dam No. 2 (Arkansas River Navigation System), AR	302	ML	2.31 (2.31)	-0.0125 (-0.28)	1.6×10^{-5} (64.95)	-17.67		
		OLS	2.31 (9.76)	-0.0125 (-2.30)	-1.8×10^{-5} (-1.08)	-	0.14	38
Belton Lake, TX	304	ML	2.94 (4.62)	-0.0727 (-2.70)	1.2×10^{-5} (0.42)	-23.61	-	-
		OLS	1.69 (9.38)	-0.0052 (-2.47)	2.6×10^{-6} (0.29)	-	0.12	50
Benbrook Lake, TX	305	ML	2.45 (1.54)	-0.0472 (-1.09)	8.3×10^{-5} (0.60)	-16.01	-	-
		OLS	1.83 (10.70)	-0.0054 -4.11)	6.0×10^{-6} (0.80)	-	0.30	43
Blakely Mt. Dam, Lake Ouachita, AR	307	ML	2.44 (24.03)	-0.0374 (-13.63)	-9.6×10^{-6} (-0.88)	-18.17	-	-
		OLS	1.70 (10.08)	-0.0079 (-5.14)	-7.6×10^{-6} (-0.98)	-	0.24	88
Canton Lake, OK	308	ML	3.96 (8.94)	-0.2788 (-12.50)	1.4×10^{-4} (11.23)	-12.51	-	-
		OLS	1.77 (8.61)	-0.0206 (-5.28)	7.1×10^{-6} (0.86)	-	0.28	71
Cordell Hull Dam and Reservoir, TN	310	ML	2.91 (87.61)	-0.0657 (-22.02)	3.8×10^{-6} (0.90)	-29.26	-	-
		OLS	1.86 (14.13)	-0.0139 (-6.00)	-1.2×10^{-8} (-0.01)	-	0.34	101
DeGray Lake, AR	311	ML	2.36 (3.55)	-0.0267 (-1.57)	-1.5×10^{-5} (-0.56)	-17.81	-	-
		OLS	1.79 (7.71)	-0.0070 (-3.00)	-6.9×10^{-5} (-0.73)	-	0.17	46
Grapevine Lake, TX	314	ML	2.71 (6.41)	-0.0311 (-3.43)	1.8×10^{-5} (1.42)	-26.92	-	-
		OLS	1.80 (16.12)	-0.0073 (-8.80)	8.5×10^{-6} (1.70)	-	0.47	89
Greers Ferry Lake, AR	315	ML	2.10 (15.91)	-0.0287 (-9.84)	2.8×10^{-5} (3.20)	-51.84	-	-
		OLS	1.48 (14.08)	-0.0065 (-9.02)	8.4×10^{-6} (1.42)	-	0.28	214
Grenada Lake, MS	316	ML	4.92 (8.97)	-0.0924 (-4.58)	-3.5×10^{-5} (-0.58)	-29.47	-	-
		OLS	2.04 (12.61)	-0.0095 (-4.36)	-1.0×10^{-5} (-0.68)	-	0.22	73

(continued)

TABLE 4 (continued)

Site name	Site No.	Estimator	Intercept	T+M cost	Income	Function value	R^2	df
Hords Creek Lake, TX	317	ML	2.77	-0.0502	-6.5×10^{-5}	-13.49	-	-
			(5.07)	(-2.38)	(-2.22)			
		OLS	1.73	-0.0050	-2.1×10^{-5}	-	0.19	51
			(8.22)	(-2.11)	(-1.76)			
Melvern Lake, KS	322	ML	-2.42	-0.1797	7.4×10^{-5}	-14.17	-	-
			(-2.19)	(-20.00)	(2.56)			
		OLS-I	1.30	-0.0079	4.1×10^{-6}	-	0.06	42
			(4.47)	(-1.66)	(0.32)			
Millwood Lake, AR	323	ML	1.43	-0.0331	7.4×10^{-5}	-20.14	-	-
			(2.97)	(-6.15)	(2.97)			
		OLS	1.43	-0.0081	1.8×10^{-5}	-	0.25	50
			(7.94)	(-3.99)	(2.14)			
Mississippi River Pool 6, MN	325	ML	1.49	-0.0565	5.8×10^{-5}	-22.21	-	-
			(2.67)	(-1.75)	(1.41)			
		OLS	1.41	-0.0074	1.3×10^{-5}	-	0.22	68
			(7.45)	(-4.39)	(1.53)			
New Savannah Bluff Lock & Dam, GA	329	ML	3.28	-0.0538	-5.6×10^{-5}	-19.51	-	-
			(2.24)	(-0.68)	(-0.59)			
		OLS	1.88	-0.0067	-9.8×10^{-6}	-	0.06	36
			(8.39)	(-1.44)	(-0.70)			
Ozark Lake, AR	331	ML	1.98	-0.0230	1.2×10^{-5}	-8.27	-	-
			(3.70)	(-14.25)	(0.36)			
		OLS	1.66	-0.0046	-8.8×10^{-6}	-	0.31	49
			(8.52)	(-4.44)	(0.66)			
Philpott Lake, VA	333	ML	2.21	-0.0335	2.2×10^{-5}	-8.80	-	-
			(4.77)	(-22.71)	(0.80)			
		OLS	1.90	-0.0087	-1.7×10^{-6}	-	0.36	35
			(9.28)	(-4.40)	(-0.13)			
Proctor Lake, TX	337	ML	4.09	-0.0643	5.0×10^{-6}	-6.63	-	-
			(6.59)	(-2.14)	(0.27)			
		OLS	2.06	-0.0134	1.2×10^{-6}	-	0.54	49
			(13.61)	(-7.50)	(0.19)			
Sam Rayburn Dam & Reservoir, TX	339	ML	1.60	-0.0744	1.0×10^{-5}	-14.41		
			(1.64)	(-2.52)	(0.23)			
		OLS	1.46	-0.0094	1.0×10^{-6}	-	0.11	64
			(7.06)	(-2.83)	(0.13)			
Sardis Lake, MS	340	ML	2.48	-0.0095	1.5×10^{-5}	-100.97	-	-
			(7.01)	(-2.05)	(0.64)			
		OLS	1.81	-0.0030	4.3×10^{-6}	-	0.05	202
			(20.73)	(-3.17)	(0.78)			
Whitney Lake, TX	344	ML	-0.378	-0.0166	3.0×10^{-5}	-98.95	-	-
			(-0.17)	(-1.04)	(0.83)			
		OLS	1.41	-0.0025	3.2×10^{-6}	-	0.02	201
			(13.07)	(-1.80)	(0.72)			

substantial differences in the results. Water quality, as measured using dissolved oxygen, has a positive and statistically significant effect on the intercept but not the other two estimated demand parameters. Moreover, the record with respect to the other site characteristics is not as good as was reported for the first generation version of the model. Few characteristics would be judged to be significant determinants of these site demand parameters. Thus, these results taken alone do not provide a compelling case for accepting the revised model based on the ML estimates of site demand parameters.

However, we should note that our size is relatively small and the degree of discrimination required of these models is quite demanding. This is compounded by the quality of available data on both water quality and other site characteristics. Nonetheless, we must conclude that our attempts to improve the site demand estimates has led to more questions about the plausibility of the second stage equations for the generalized travel cost model.

To evaluate the implications of this revision to the generalized travel cost model, we completed two sets of comparisons. First, Table 5 presents estimates of the incremental changes in Marshallian consumer surplus for two levels of improvement in water quality for each version of the model across a range of different sites. These benefits are calculated for a "representative" user of each site who has the average travel cost as his price, the maximum travel cost as the choke price, and the average household income of users of each site. In the three columns following the site number code of Table 6, the specific values for each of these variables are reported. The remaining four columns report the estimated benefits per season (in 1977 dollars) for two water quality improvements--boatable to fishable and boatable to swimmable--conditions. Both changes are measured using dissolved oxygen and the standards defined by Vaughan [1981].[17]

Several results from this table are quite striking. For example, the estimates based on our first generation model are substantially larger than those of the ML based model. Improvements from boatable to fishable range from $39.97 for the Arkansas River to $155.73 for Millwood Lake. By contrast, the ML estimates are as low as $0.39 with the largest estimate for Millwood Lake of $33.62. As a percent of the first generation results, the ML estimates range from 0.4 percent to 72 percent. However, most sites fall within a somewhat narrower range of 3 percent to 33 percent. Thus, these results imply a substantial difference in the valuations derived from each of the two models.

Our second comparison attempts to gauge the plausibility of each set of estimates based on what has been found in earlier studies of the recrea-

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[17]The values for dissolved oxygen are given as follows: (a) improvement from boatable to fishable is assumed to be associated with a change from 45 to 64 percent saturation; (b) improvement from boatable to swimmable is assumed to be associated with a change from 45 to 83 percent saturation.

TABLE 5. GENERALIZED LEAST-SQUARES ESTIMATES USING MAXIMUM LIKELIHOOD SITE DEMAND ESTIMATES

Independent variables[a]	Intercept	Travel cost parameter	Income parameter
Intercept	-0.044 (-0.024)	-0.022 (-0.431)	0.17×10^{-4} (0.657)
Shore	0.001 (0.782)	-0.11×10^{-4} (-0.382)	-0.60×10^{-7} (-1.449)
Access	-0.039 (-1.071)	0.27×10^{-2} (1.301)	0.14×10^{-6} (0.074)
Water pool	1.461 (1.030)	-0.089 (-1.522)	-0.86×10^{-4} (2.731)
DO	0.020 (2.076)	-0.10×10^{-3} (-0.286)	-0.24×10^{-6} (-0.766)
VDO	-6.47×10^{-5} (-2.077)	1.48×10^{-7} (0.127)	5.28×10^{-10} (0.573)
R^2	0.475	0.196	0.455
F	2.89	2.50	2.68

[a]Definitions for the site characteristics are:

Shore: Total shore miles at side during peak visitation period.

Access: Number of multipurpose recreational and developed access areas at the site.

Water pool: Size of hte pool surface relative to total site area.

DO: Dissolved oxygen (percent saturation).

VDO: Variance in dissolved oxygen.

TABLE 6. A COMPARISON OF BENEFITS ESTIMATES FOR WATER QUALITY IMPROVEMENTS FOR THE FIRST AND SECOND GENERATION MODELS[a]

Site	No.	Average income	Average travel cost	Maximum travel cost	Boatable to fishable		Boatable to swimmable	
					First	Second	First	Second
Arkabutla Lake, MS	301	13,184	20.04	209.35	104.57	29.37	274.20	66.13
Lock & Dam No. 2 Arkansas River, AR	302	10,409	3.04	70.01	33.37	29.01	83.45	67.42
Belton Lake, TX	304	17,279	33.18	302.86	115.84	9.62	331.45	21.34
Benbrook Lake, TX	305	19,135	30.23	344.44	124.64	6.53	366.68	14.52
Blakey Mt. Dam, Lake Ouachita, AR	307	17,144	45.39	286.03	43.54	3.38	131.73	7.41
Canton Lake, OK	308	17,392	32.30	106.16	42.83	4.90	101.59	10.94
Cordell Hull Reservoir, TX	310	15,491	29.65	184.35	68.75	14.21	173.75	31.52
DeGray Lake, AR	311	19,235	42.04	210.48	82.72	10.37	218.39	22.59
Grapevine Lake, TX	314	19,309	38.45	307.28	114.12	3.86	323.63	8.51
Grenada Lake, MS	316	9,199	24.57	207.05	99.16	19.17	262.04	43.53
Hords Creek Lake, TX	317	16,263	33.46	304.01	112.35	3.11	321.87	6.89
Melvern Lake, KS	322	18,087	31.48	130.50	56.21	5.46	136.35	12.14
Millwood Lake, AR	323	18,630	37.62	309.24	155.73	33.62	461.81	74.15
Mississippi River Pool No. 6. MN	325	19,589	52.23	843.86	100.17	0.39	300.51	0.84
New Savannah Bluff Lock & Dam, GA	323	12,609	18.65	157.36	84.32	13.07	209.64	29.53
Ozark Lake, AR	331	12,654	58.71	457.44	94.66	6.34	291.05	14.07
Philpott Lake, VA	333	14,268	26.09	268.76	117.99	16.79	328.58	37.54
Proctor Lake, TX	337	17,510	46.08	172.41	68.93	0.82	178.22	1.80
Sam Rayburn Dam & Reservoir, TX	339	19,515	40.23	155.30	49.30	9.35	122.62	20.46
Sardis Lake, MS	340	13,141	36.08	429.20	128.98	9.19	338.58	20.46
Whitney Lake, TX	344	18,688	35.40	303.62	109.70	6.73	315.02	15.03

[a]These are the Marshallian consumer surplus estimates for each site using the maximum travel cost in each case as a finite choke price.

tion values of water quality improvements. Table 7 presents the first water quality change--boatable to fishable--and compares our estimates with the second generation framework reported estimates (including our own earlier work [Smith, Desvousges, and McGivney, 1983a]). Table 7 reports the estimates derived from the travel cost models on both a per-trip and a per-day basis in 1982 dollars.[18]

Two aspects of these results are especially important. First, our initial model's benefit estimates for the Corps sites are substantially outside the range from past studies for these types of recreation areas. However, when the model was applied to the Monongahela River sites, its estimates clearly fall within the range anticipated by past experience. This discrepancy in performance accentuates the importance of site characteristics. That is, the characteristics of the Monongahela sites are substantially smaller and have fewer access points, but have a larger fraction of each site's area associated with water (i.e., the river) than the other Corps sites. Thus, using the first generation of the model to predict the demand for the Monongahela River site was a projection substantially outside the range of values for the site characteristic variables.

By contrast, the second generation model provides benefit estimates for the Corps sites that are more consistent with the valuations for water quality improvements obtained with earlier studies. Thus, we have an unusual example of a situation in which the parameter estimates do not provide a strong case for a model but the end use of its estimates does.[19]

VI. IMPLICATIONS

Several implications for future research emerge from our discussion of the varying parameter model and its relationship to other recent recreation demand models.

- The varying parameter model is a plausible practical model for valuing the changes in site characteristics. Its main weaknesses stem from inadequate data on substitute sites and

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[18]These are based on the average number of trips for each site and the average number of days reported for the trip in which the respondents to the survey were interviewed. Actual trips were selected rather than predicted trips because the latter will be a biased estimate from a semi-log function. Moreover, there are additional problems in selecting the predicted number of trips for normalization. There are predictions available at each level of water quality that might be used as the base in evaluating each water quality change. Since the actual water quality conditions at these sites often were closer to or exceeded fishable conditions, actual use was judged to provide a better normalizing factor than the available estimates.

[19]See Klein et al. [1978] for a general discussion of these issues as they relate to selecting an objective function for selecting statistical estimators of the parameters of economic relationships.

TABLE 7. A COMPARISON OF ALTERNATIVE ESTIMATES OF THE BENEFITS OF WATER QUALITY IMPROVEMENTS FROM BOATABLE TO FISHABLE CONDITIONS IN 1982 DOLLARS[a]

Study	Original estimate	1982 dollars
Vaughan-Russell [1982]	$4.00 to $8.00 per person per day was the range over the models used (1980 dollars)	$4.68 to $9.37
Loomis-Sorg [1982]	$1.00 to $3.00 per person per day over regions considered; based on increment to value of recreation day for cold-water game fishing (1982 dollars)	$1.00 to $3.00
Smith, Desvousges, and McGivney [1983a]	$0.98 to $2.03 per trip using first generation generalized travel-cost model with Monongahela sites, boatable to fishable water quality (1981 dollars)	$1.04 to $2.15
First Generation Generalized Travel Cost Model	$5.87 to $54.20[b] per trip ($2.24 to $122.00 per visitor day[c]) for Corps sites, change from boatable to fishable water quality (1977 dollars)	$9.35 to $86.34 ($3.57 to $194.35)
Second Generation Generalized Travel Cost Model	$0.08 to $5.43 per trip ($0.04 to $18.78 per visitor day) for Corps sites, change from boatable to fishable water quality (1977 dollars)	$0.13 to $8.65 ($0.06 to $29.92)

[a]The Consumer Price Index was used in converting to 1982 dollars. The scaling factor for the conversion from 1977 to 1982 was 1.593.

[b]These estimates relate only to the Marshallian consumer surplus (M2).

[c]The reason for the increase in the range for benefits per day is that some trips were reported as less than a day. The appropriate fractions were used in developing these estimates.

jointly produced recreation activities. Yet the other recent studies all seem to require some type of unrealistic assumptions about household behavior.

- Data quality is important. All of the recent studies are hampered by inadequate data. Attempts to improve the quality of data collection for indirect or revealed preference models would pay handsome dividends.

- Focus groups with a relatively small number of recreators in group discussions could yield valuable insights about the household's decision process for recreation. Topics could include discrete nature of decisions, perceptions of site attributes, and the nature of household production of recreation activities.

- Statistical problems like truncation and censoring can have substantial effects on the benefit estimates derived from travel cost models. Studies that fail to deal with these problems may have significant estimation problems.

- Contingent valuation and the travel cost approach are good complements. Data required for one approach can prove useful for the other.

The recent models valuing quality changes are significant improvements over their predecessors. Yet further improvements await better understanding of household's recreation decisions and dramatically better data.

VII. REFERENCES

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VALUING QUALITY CHANGES IN RECREATIONAL RESOURCES

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ABSTRACT

From a general consumer utility maximization model, which describes a consumer's quality and quantity choices, a number of specific models are derived, including multiple site travel cost models, and the hedonic model. However, the transition from the general model to estimation of the parameters involves dealing with a number of issues. These include parameter identification, the use of weak complementarity and path-independence assumptions, and the question of whether the estimated demand curves are adequate approximations to compensated demand curves. These issues are explored for each of the specific models. One of the models, the hedonic model, is estimated, and applied to the valuation of quality changes in deer hunting sites in the Black Hills National Forest of South Dakota.

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I. INTRODUCTION

Biologists and ecologists have for some time been aware that forest management practices can affect wildlife populations through their influence on the availability of desirable wildlife habitat.[1] Scientists who study human motivations in a recreational setting have known that the satisfactions hunters derive from hunting experiences are influenced both by the environment in which the hunting takes place and by whether or not they are successful.[2] However, unlike such forest products as timber, wildlife habitat and pleasing recreational environments do not have readily observable market prices. For public agencies charged with the management of forest resources, this has made provision of outputs such as timber, for which the benefits are easily determinable, easier to justify than nonmarket resources services such as wildlife habitat or pleasing recreational environments, for which benefits are not easily measured.

Assessment of the demand for and value of these nonmarket resource services can help to strengthen the underpinnings for multiple use management practices. However, because what forest management practices do is change the levels of resource services available at locations in the forest, it is necessary that primary emphasis be placed on valuing changes in the levels of resource services provided. The next section of this paper will set out a general model for the measurement of the economic efficiency benefits from management practices that increase the level of certain resource services (deer habitat and a desirable hunting environment). From the general model a number of specific models can be derived, including a number of variants of the travel cost model, and the hedonic travel cost model. These specific models are discussed in section III, where consideration is given to the assumptions involved in identifying the relevant demand curves, and using them to value resource service changes. Finally, in section IV one of these models, the hedonic travel cost model, is estimated and wildlife habitat improvement benefits to hunters in the Black Hills National Forest in South Dakota are calculated.

II. THE GENERAL MODEL

(i) Background

In general two types of approaches are possibilities for measuring the economic efficiency benefits from the provision of wildlife habitat and a pleasing hunting environment for hunters. One, the contingent valuation approach, uses direct questioning techniques to obtain values for hunting days, visits or seasons, or simply for the existence of certain types of wildlife. This approach is exemplified by the work of Mitchell and Carson (1981), Brookshire, Thayer, Schulze and d'Arge (1982), Desvouges, Smith and McGivney (1982), Bishop, Heberlein and Keely (1983), and Brookshire, Eubanks and Randall (1983). The other approach, and the one which is used here, uses information on the actual behavior of hunters to infer the benefits they derive.

More specifically, the behavior that is observed in the second approach is the hunter's choice of a hunting site. A forest environment can be viewed as providing a set of hunting sites. Hunting benefits have often been assessed directly in terms of hunters' demands for visits to these sites using a consumer's surplus measure of benefit. However, the demands for visits to these sites can be viewed as being derived from the attributes or characteristics of the sites and demands may be assessed for these characteristics. The consumer's surplus approach can then be used to assess benefits associated with obtaining a certain level of the characteristic or of a change in the availability of the characteristic.

In the case of recreational deer hunters, at least one of the relevant characteristics would be expected to be the probability of bagging game. The literature on the motivations of hunters (Potter, Hendee and Clark [1973]; More [1973]; and Stankey and Lucas [1973]) shows that bagging game is a necessary, although not necessarily the most important, element of a recreational hunting experience. Hence vegetative characteristics that provide desirable habitat for game are likely to have some appeal for hunters. However, it is also true that vegetative and landform characteristics that provide a pleasing landscape for hunters will be important.

Given that forest vegetative characteristics can affect the hunter's recreational experience both directly and indirectly, through the provision of wildlife habitat, management practices which affect these vegetative characteristics are likely to affect the quality of the hunting experience and therefore the benefits provided to hunters. What is done in this paper is to use observations on hunter choices of sites in the Black Hills National Forest, along with information on the costs associated with these choices, to assess the benefits associated with management practices that increase the availability of desirable hunting sites.

(ii) The Formal Model

The model used in this study is a consumer utility maximization model. The consumer chooses site quality, the number of recreation visits, and the amounts of other goods and services to consume, based on his utility function, his budget constraints, and the prices or marginal. costs of quality units, visits and other goods and services. Here the numeraire good X represents all other goods and services, and the utility function is assumed to be weakly separable such that neither the marginal utility of visits nor the marginal utility of quality is affected by the level of X. Nor is the marginal utility of X affected by the level of visits or quality. The cost function for visits is assumed to be such that the cost of each visit has a fixed component that is independent of the quality choice, and a variable component that depends upon the quality choice.

Let the recreationist's utility function be

$$U(x) + U(n,q) \tag{1}$$

where: x is a numeraire good;
n is the number of visits;
q is the site quality characteristic.

The cost function is assumed to be of a form such that the marginal cost price of a visit can be changed without affecting the choice of q. The cost function is

$$c = x + (h + K(q))n \tag{2}$$

where: h is the part of the cost of a visit which is independent of q;
K(q) is the part of the cost of a visit which depends upon q;
the price of the numeraire good is unity.

The first-order conditions for n and q are

$$\frac{U_n}{U_x} = h + K(q) \tag{3}$$

$$\frac{U_q}{U_x} = n \cdot K_q \tag{4}$$

In general, (3) and (4) imply a simultaneous equation system with four unknowns, n and q, and their prices. The change in the resource service is modeled as a shift in K_q, and what must be measured is the benefit (consumer's surplus change) from this shift. However, in its general form the household production function model is not particularly useful for estimation purposes, or for calculating consumer's surplus changes. In deriving, from this general model, a more specific model, which can be estimated, and will allow consumer's surplus calculations to be made, there are a number of issues which must be addressed. These can be grouped into four categories.

1) Can the parameters of the cost and demand functions be identified?

2) Can weak complementarity be assumed?

3) Is the line integral measurement of consumer's surplus path independent?

4) Can it be assumed that the measurable Marshallian demand curve is a reasonable approximation for the compensated demand curve?

These categories are not entirely independent of one another. The assumption of weak-complementarity can limit the number of demand and supply curves that need to be identified. If the Marshallian and compensated demand curves are equivalent, path-independence in the measurement of consumer's surplus is guaranteed. In the next section some specific models that can be derived from the general model are considered, with a view to how each specific model deals with these four issues.

III. SPECIFIC MODELS

(i) The Single Site Travel Cost Model

If there is only one site, then q is perfectly inelastically supplied, and can be taken as exogenous. This means that the demand-supply system is reduced to the two equation system containing the demand and supply curves for n. Since q is not a choice variable, the marginal cost of n is simply h, which is also exogenous. This leaves the demand curve for n, the only relationship requiring estimation, identified.

If q is an exogenous predictor variable in the demand curve for n, then an increase in q at the site will shift the demand curve, and there will be a consumer's surplus change. Does this change measure the benefit the consumer obtains from the increase in q? This depends upon the answers to the second, third and fourth questions posed in section II.

First consider the weak complementarity assumption. This assumption says that if n = 0, $U_q = 0$ (Mäler [1974]). If there are no visits taken to the site, an increase in q yields zero marginal utility. This assumption is usually regarded as a reasonable one, and its use ensures that there is no additional benefit from the change in q that is not measured by the change in the area under the compensated demand curve for n.

The final two issues both are related to the fact that, in general, the estimated demand curve will be a Marshallian demand curve, and not a compensated demand curve. The former incorporates income effects, the latter does not.

The path-independence assumption is important because, in general, a shift in the supply curve for q will mean that the consumption of both q and n will change. Path-independence is required in order for the benefit measure to be unique. If $g_1(n,q,x)$ is the inverse demand function for n, and $g_2(n,q,x)$ is the inverse demand function for q (with x as the income level) path-independence on the demand side requires that $g_{1q} = g_{2n}$. That is, the income effects embodied in the changes in q and n must be the same. On the cost side the path-independence assumption requires that $C_{qn} = C_{nq}$. In this case $C_{nq} = C_{qn} = 0$, since C = hn.

Finally, there is the question of whether the estimated Marshallian demand curves are reasonable approximations to the compensated demand curves which correctly measure the welfare gains or losses from exogenous changes. In the general model the assumptions of a constant U_x and $U_{qx} = U_{nx} = 0$ are sufficient to ensure that the Marshallian and compensated demand curves are equivalent. In any specific case these are unlikely to hold exactly. However, as Willig (1981) has shown, if q and n account for only a small portion of the consumer's total budget, then the income effects associated with the changes in n and q will be small, and the Marshallian demand curves will be reasonable approximations to the compensated ones. As a practical matter it is possible to estimate income elasticities of demand for n and q. If they are small, the Marshallian demand curve will suffice. If they are large, then an approach, such as that suggested by Hausman (1981) may be required to calculate the compensated demand curves from the Marshallian demand curves. In general the approach used in travel cost models is to assume explicitly or implicitly that the Marshallian demand curve is an adequate approximation.

(ii) The Multi-Site Travel Cost Model

Cross-sectional data with multiple sites are usually used to obtain the variation in q necessary to estimate the effect of a shift in q. In the simplest case it is assumed that each consumer still faces a perfectly inelastic supply curve for q. However, since different sites are of different quality, exogenous variation in the level of q is introduced. Although there are multiple sites, from the point of view of any given consumer there are no substitute sites. A comparison of the consumer's surpluses generated by sites with different levels of q, measures the benefit from an increase in q. This is essentially the model used by Desvouges, Smith and McGivney (1982), and by Vaughan and Russell (1982). It can be written as:

$$n_{ij} = f(q_i, h_{ij}) \qquad (5)$$

where: n_{ij} = visits to site i by a consumer at location j;
q_i = quality level of site i;
h_{ij} = cost of visiting site i from location j.

If the no substitutes model is not considered to be appropriate then the prices and qualities of substitute sites need to be included as predictors, and (5) becomes:

$$n_{ij} = f(q_i, h_{ij}, q_k, h_{kj}, q_\ell, h_{\ell j}, \ldots, q_z, h_{zj}) \qquad (6)$$

where: k through z are substitute sites for i.

Now an increase in q must be simulated by a comparison between sites with different q_i, but the same prices and quantities for the substitute sites, k through z. There is a question of how to specify the substitute sites. Site k, for example, could be a specific site, or it could be merely a site of a specific quality level. If the former specification is used, then it will be difficult to hold all of the costs of visiting the substitute sites constant, while increasing h_{ij}.

It may be easier to replace the substitute price and quality terms with an index of overall substitute availability and quality. This is what is done in the multiple site travel cost models, such as those of Cesario and Knetsch (1976).

The second alternative is to group together sites of a given quality level, and identify them as site type k. The substitute cost variable for site type k, for an individual from location j, is the minimum cost required to visit a site of type k. Burt and Brewer (1971), and Cicchetti, Fisher and Smith (1976) used this type of model. Suppose there are m site types. Then for an individual at location j a system of m demand equations exists.

$$
\begin{aligned}
n_{ij} &= f_1(h_{1j}, h_{2j}, h_{3j}, \ldots, h_{mj}) \\
n_{2j} &= f_2(h_{1j}, h_{2j}, h_{3j}, \ldots, h_{mj}) \\
&\vdots \\
n_{mj} &= f_m(h_{1j}, h_{2j}, h_{3j}, \ldots, h_{mj})
\end{aligned}
$$

Now an increase in q at a given site changes its site type. This means that the price of a higher quality site type is lowered, and the price of a lower quality site type is increased. The original consumer's surplus amount can be measured by starting with the original h_1 through h_m, and increasing them until n_1 through n_m all equal zero. The new consumer's surplus (after the site type change) is measured in the same way, except that the altered price set is used as the starting price set. The benefit measure is the difference between the old and new consumer's surplus amounts.

There is another way to use the model in (7). Since n_{1j} through n_{mj} are all functions of h_{1j} through h_{mj}, the sum of n_{1j} through n_{mj} must also be a function of h_{1j} through h_{mj}. Now define

$h_j = \min(h_{1j}, h_{2j}, h_{3j}, \ldots, h_{mj})$, and $K_j(q_1)$ through $K_j(q_m)$ equal to $h_{1j} - h_j$ through $h_{mj} - h_j$ respectively. The demand system in (7) can be written as:

$$n_j = f(h_j + K_j(q_1), h_j + K_j(q_2), h_j + K_j(q_3), \ldots, h_j + K_j(q_m)), \quad (8)$$

OR

$$n_j = g(h_j, K_j(q_1), K_j(q_2), K_j(q_3), \ldots, K_j(q_m)). \quad (9)$$

NOW a consumer's surplus calculation for a given set of $K_j(q_1)$ through $K_j(q_m)$ can be carried out by increasing h until $n_j = 0$. A change in some of the $K_j(q_1)$ through $K_j(q_m)$ can be made and the consumer's surplus recalculated. The difference between the new and old consumer's surpluses measures the benefits from the change in site type.

The multiple site models all rely on identification of demand curves for visits to sites. These demand curves are identified because site prices are exogenous. Since weak complementarity ($U_q = 0$ and $C_q = 0$ when n = 0) is either explicitly or implicitly assumed, identification of visit demand curves is sufficient to allow measurement of benefits from changes in q, or in some of the $K_j(q_1)$ through $K_j(q_m)$.

In the no substitute case, or when the prices and qualities of substitutes remain unchanged, the path-independence conditions, and the conditions to ensure approximation of the compensated demand curves, are as discussed in section III (i). In the multiple site model used by Burt and Brewer (1971), the q change is replaced by multiple price changes. Path independence requires that the income effects associated with each of the price changes be the same. Close approximation to the compensated demand curves requires that the income effects associated with these price changes are small. When (7) is replaced by (8) or (9)

K_{jq} is perfectly elastic, then a fixed K_{jq} is equivalent to a fixed set of $K_j(q_1)$ through $K_j(q_m)$ in (8) or (9), and (10) can be identified. In the more general case the $K_{jq}(q)$ function will have an endogenous component, which depends upon the level of q chosen, and an exogenous component (E_j) depends upon the consumer's location relative to the various sites. In this case E_j can be used as an instrument in estimating the demand curve for n.

It is also worth noting that if the utility function has a form such as (11), and the cost function is as in (2), that the choice of q will be independent of the choice of n.

$$U(x) + n\,U(q) + U(n) \tag{11}$$

This has the advantage that the system of four simultaneous equations' in n and q and their marginal cost prices can be treated as a block recursive system, q and K_{jq} are determined by the first block (containing the demand and marginal cost curves for q), and can be treated as exogenous in the second block (containing the demand and marginal cost curves for n). This result is also quite sensible, in that it allows the choice of q for a given visit to be taken independently of the number of visits.

So far we have determined that a demand curve for n can be identified. With the usual weak-complementarity assumption, the benefit from an exogenous increase in q (or decrease in K_{jq}) can be measured by the change in the area under the demand curve for n, and above the marginal cost curve for n. However, there may be cases in which h_j does not exhibit sufficient variation to allow the demand curve for n to be estimated, or n does not exhibit variation. In these cases it may be worthwhile to consider estimating the demand curve for q.

Consider the first case where h_j is invariant, but n does exhibit variation. Let $h_j(q) = K(q,E_j)$, where E_j is the exogenous shift component - dependent on variation in origin location. Assume two alternative forms of the utility function.

First assume the form in (11), where the consumer's choice of q is the same for every unit of n. Then if $U_n = 0$ and $C_n = 0$ when q = 0 the demand and supply curves for q can be used to calculate the consumer's surplus from one visit. Since each visit yields the same consumer's surplus, n sill either stay at its original level, or be reduced to zero, depending upon the level of E_j. This means the total consumer's surplus change is the change for one visit multiplied by the original level of n. However, unless $h_j = 0$, the $C_n = 0$ assumption will not hold. This means that if the E_j change is great enough to reduce n to zero, nh_j must be netted out in measuring the consumer's surplus loss.

Alternatively assume the utility function has the form of (12).

$$U(x) + U_1(q_1) + U_2(q_2) + U_3(q_3) + \ldots + U_n(q_n) \qquad 12$$

where: the subscripts refer to visits 1 through n.

In this case n will change as E_j changes. If the marginal utility functions for q for each visit are constant as E_j shifts, and $U_n = C_n = 0$ when q = 0, the consumer's surplus change for each visit can be measured. The changes are then aggregated over the visits to obtain the total consumer's surplus change. However, again C_n will not equal zero. Here this means that in general $h(\Delta n)$ must be netted out in measuring the total consumer's surplus change. If the E_j change reduces q to zero, Δn becomes n.

If n is invariant, although h_j and E_j change, then either the supply of n must be fixed, due to some constraint like a fixed season length, or the utility function must have a form like (13).

$$U(x) + n\,U(q) \tag{13}$$

This is the same form as (11) but with $U_n = 0$. With this utility function n will remain at its original level until $h_j + K(q,E_j)$ is increased to the point where a visit yields no consumer's surplus. At that point n becomes zero. With (13) as the utility function, n can be regarded as indeterminate. That is, the variables h_j and $K(q,E_j)$ do not affect its level, only whether it will be zero or positive.

Whether n is fixed on the supply side, or indeterminate because of the nature of the utility function, n can be treated as exogenous in the demand and supply curves for q. If it does not exhibit significant variation it may be omitted as an explanatory variable.

If n is exogenous, weak complementarity conditions are only of concern for the cost side, and only if E_j before (or after) the shift is such as to reduce q to zero. In such a case hn must be netted out in measuring the consumer's surplus change.

If the hedonic model results in changes in both n and q (or changes in q_1 through q_n) then path-independence must also hold. However, if n does not change the conditions are irrelevant, because there is only one path. Finally the Marshallian demand curves should be reasonable approximations to the compensated demand curves. If n is fixed, this requires only that the income effect of the change in E_j be small.

There is another variant of the hedonic model, which is essentially the simple repackaging model of Fisher and Shell (1971) and Muelbauer (1974). It is particularly relevant if the characteristic q is a variable similar to "the probability of bagging game," which must be defined over a fixed time period. In such cases, the utility function in (13), might better be written as:

$$U(x) + U(Q) \tag{14}$$

where: $Q = nq$.

With (14) as the utility function and (2) as the cost function, the first order conditions can be summarized as:

$$U_q = K_q = \frac{h + K(q)}{q} \tag{15}$$

With this model n can still be exogenous, if it is fixed by some constraint on the supply side. However, the utility function in (13) will not result in the choice of n being indeterminate. But, even if n is determined by (15), it is still possible, because the production function $Q = n_q$ is known, to calculate the demand for q, and the benefit from a change in E_j, as if n were fixed (Wilman 1984). However, since n is fixed only arbitrarily, the path-independence and compensated demand curve approximation conditions will need to involved both n and q.

iv Multiple Characteristics

So far site quality has been described in terms of one characteristic. However, it is possible that site quality really has more than one dimension. Here it is assumed that that site quality has two independent dimensions q and s, and that the consumer makes his choice of site taking into account both of these dimensions. However, only one of these, q, is assumed to be manageable.

The second characteristic, s, complicates matters only if s, or its marginal cost price, cannot be treated as to be predetermined in the demand and supply curves for n or q. If s is exogenous, then it can be assumed to remain constant as the price of n and q (or its marginal cost) are varied. With no change in s, path-independence conditions are not altered, and there are no additional income effects to consider in evaluating the extent to which the Marshallian demand curve approximates the compensated demand curve.

If s is not exogenous, but its marginal cost price is, then the latter can be assumed to remain constant as the price of n, and q (or its marginal cost) varies. Using the approach of shifting the demand curve for n, the weak complementarity assumptions need to be extended to include $U_s = 0$ and $C_s = 0$ when n = 0. The path-independence assumptions must be extended to include $g_{3q} = g_{2s}$, $g_{3n} = g_{1s}$, $C_{sq} = C_{qs}$ and $C_{sn} = C_{ns}$, where $g_1(q,s,n,x)$, $g_2(q,s,n,x)$ and $g_3(q,s,n,x)$ are the inverse demand curves for n, q and s respectively. If the Marshallian demand curves are to approximate the compensated demand curves, then it must additionally be true that the income effects implicit in the changes in s are small. If the demand for q is to be estimated, with n fixed, then the additional conditions required are the same, except in the case of path-independence, where any conditions involving n can be ignored.

If neither s nor its marginal cost are totally exogenous, then there must be some exogenous shift variable, on either the demand or supply side, which affects s but not q. This can be used as an instrument in the demand curve for n, or, if n is fixed, in the demand curve for q. The weak complementarity and path-independence conditions are as discussed above, and the income effect implicit in any change in s should be small if the Marshallian demand curve is to approximate the compensated demand curve.

(v) <u>The Model Used in the Case Study</u>

The hedonic travel cost model was used in the case study. This was in part because, the data collected exhibited little variation in h_j, and in part because the quantity variable, n, was observed to have very little variation. Two quality variables, q and s, were used, although only q was manageable.

In estimating the hedonic model it was necessary to treat the quantity variable as days, rather than visits. Although the latter is more common in travel cost models, the latter was used here for two reasons. First, when the probability of bagging game (or a proxy for it) is used as a quality characteristic, that probability must be calculated for a given time period. Second, it was apparent in observing the pattern of tradeoff between visit length and the number of visits that Black Hills deer hunters regarded the two as perfect substitutes. A hunter would take only one long visit or many one-day visits depending upon the relative cost of a day used to increase visit length versus a day used as an additional visit. Hunters close to the Black Hills took a number of one-day visits. Hunters further away took only one long visit. This suggests that the hunters themselves treated the day, rather than the visit, as the quantity unit of consumption. The assumption of a fixed n is reasonable if n is measured in days, but not if n is measured in visits. Using n_v as visits and n_ℓ as days per visit, with γ as the marginal cost of an extra day of visit length, two versions of the hedonic model were estimated.[3]

Version One: The quantity variable n is assumed fixed.

Utility function: $U(x) + U_1(n,q) + U_2(n,q,s)$ (16)

Cost function: $x + n_v[h + K(q) + J(s,q) + \gamma n_\ell]$ (17)

First order conditions for q and s:

$$U_{1q}/U_x + U_{2q}/U_x = n_v[K_q + J_q] \quad (18)$$

$$U_{2s}/U_x = n_v J_s \quad (19)$$

Version Two: $Q = nq$.

Utility function: $U(x) + U_1(Q) + U_2(Q,s)$ (20)

Cost function: $x + n_v[h + K(q) + J(s,q) + \gamma n_\ell]$ (21)

First order conditions for Q and s:

$$1/U_x[U_{1Q} + U_{2Q}] = \frac{h + K(q) + J(s,q) + \gamma n_\ell}{q} \quad (22)$$

$$= \frac{\gamma n_v}{q} = (K_q + J_q)(n_v/n)$$

$$U_{2s}/U_x = n_v J_s \quad (23)$$

In case of hunters taking many one-day visits $n_v = n$. For hunters taking one long visit $n_v = 1$.

Two alternative assumptions with respect to s were used to identify the demand and marginal cost curves for q. First, it was assumed that the U_2 and J functions were such that s would be chosen independently of q or n, and could be treated as predetermined in the demand and marginal cost curves for q. Alternatively an instrument was found that could be used for s in the marginal cost and demand curves for q.

(vi) <u>Some Additional Considerations</u>

There are three potential problems that could arise, but did not prove to be too serious in this study. The first is selectively bias. This would occur if non-hunters would have tended to choose different levels of q, s or n than hunters, given the same prices. For a discussion of this problem see Heckman (1976).

Second there is the question of whether benefits are more appropriately measured using per capita (expected) quantity units or conditional quantity units. Brown and co-authors (1983) have shown that the two alternatives give different benefit estimates, and that in general the per capita measure should be used because the probability of visitation, as well as the conditional quantity level changes across travel cost zones. However, when estimating benefits from a change in site quality, rather than the full benefits from the site, it is not clear that this is a problem. The benefit from the quality change is composed of two parts: (i) the additional willingness to pay for the same expected use level, and (ii) the willingness to pay for an increase in expected use level. The first part can be measured by estimating the additional willingness to pay for the existing conditional quantity, and multiplying it by the probability of visitation. That is, conditional quantity units can be used and the adjustment for the probability of visitation made after the conditional benefits have been calculated. The second part does involve an increase in the expected use level. However, especially if the expected demand curve for quantity units is relatively inelastic, it may be quite small relative to the first part. In the hedonic model, with n fixed, a change in the probability of visitation means new visitors, and what needs to be measured is the average consumer's surplus (across new visitors) for n quantity units at the improved quality level, multiplied by the increase in the probability of participation.

Finally there is a potential problem in the observation of n, if the probability of bagging game affects the number of days hunted. If there is a bag limit, this may well be the case. The number of days hunted would be:

$$V(q,n) = 1 + (1-q) + (1-q)^2 + \ldots (1-q)^{n-1} \qquad (24)$$

where: n = the maximum number of days a hunter would take as $q \to 0$;
v = the expected number of days;
q = the probability of bagging game on a given day.

What is observed for any given hunter is one point on the distribution of V. Across a number of hunters with the same q, a mean value of V can be observed.

The question is whether it is possible to tell, by observing the V choice of hunters with the same E_j but different h_j level, if n can be taken as fixed. The relationship in (24) implies $V_q \leq 0$. If $V_q \simeq 0$, then the observed V is a good approximation to n. However, if $V_q < 0$, the level of V would be inversely related to the level of q, even if n was constant. If n is fixed and the utility function is $U(x) + V(q,n)\, U(q)$, then for the one-day visits case the first order condition for q is:

$$1/U_x[U_V V_q + V(q,n)U_q] = [h_j + K_j(q)]V_q + V(q,n)K_{jq} \qquad (25)$$

Since $V_q < 0$ an increase in h_j reduces the marginal cost of q, and there will be a tendency for q to increase, and V(q,n) to decrease. This is the same pattern that would be expected were n not fixed, and it is difficult to know much about the pattern of variation in n by observing V(q,n). Only if $V_q \simeq 0$ does the pattern of variation on

$V(q,n)$ reveal much about the pattern of variation on n. In the case of Black Hills hunters V_q is relatively small, and it seems likely that if V is invariant to changes in h_j, n will be similarly invariant.

III. THE CASE STUDY

The case under consideration involved forest management practices in the Black Hills National Forest of South Dakota. After preliminary investigation, as to the nature of the sites that seemed to be desirable due to a greater probability of success, or a greater number of hunters (correcting for accessibility), two quality attributes or characteristics were derived. One, HEIGHT, is an elevation variable. This was used as the s variable. Hunters seemed to like to get away from the main highways and back into the more rugged parts of the Black Hills. The q variable was MGDEAD. This variable is a proxy for forage provided in small openings. It was constructed using a forage variable, calculated from basal areas of ponderosa pine,[4] and a proxy variable for openings.[5] Since elevation is not a variable which can be subject to management actions, demand curves were estimated only for MGDEAD. This variable represents habitat desirability, and is therefore a good proxy for bag probability. It may also represent some aspects of the hunting environment that hunters find desirable for reasons other than a desire to bag game.

For the first version of the hedonic model the demand curve to be estimated for q is of the form

$$q = f(E,S,D) \qquad (26)$$

where S = the level of s (HEIGHT) (which is determined independently of q or n), or alternatively an instrument for s;
D = a vector of demand shifters;
E = the exogenous marginal cost price for MGDEAD, or its instrument.

The variation in E results from the fact that there are a set of five origin towns with different locations around the edge of, and within, the Forest. This is shown by Figure 1 on the following page. The towns are Rapid City, Sturgis, Custer, Hot Springs and Lead-Deadwood.

As the assumption of a fixed n is crucial, it is worthwhile to investigate whether the data support it. The following relationship was estimated for one day visits ($n_v = n$):

$$n = \underset{(0.77)}{5.52} - \underset{(0.15)}{0.05}\,h + \underset{(1.24)}{2.22}\,\text{STURGIS} + \underset{(1.21)}{6.63}\,\text{CUSTER}$$

$$\underset{(1.45)}{0.73}\,\text{HOT SPRINGS} + \underset{(1.10)}{2.67}\,\text{LEAD-DEADWOOD}$$

(standard errors in parentheses)

$R^2 = 0.17$
$F = 7.6$
$N = 191$

Support is given to the fixed n assumption, by the fact that the coefficient of h is not significantly different from zero. However, both the coefficient for Custer, and that for Lead-Deadwood are significantly different from zero. In the case of Custer, this is caused by a few influential outlying observations with very large values for n. If these observations are eliminated Custer does not have a coefficient significantly different from zero.[6] In the case of Lead-Deadwood, there is no such set of outlying observations. The question is whether this deviation from the fixed n assumption will have a significant influence on the results. This question will be reviewed below when the marginal cost of MGDEAD estimates are made.

The marginal cost curves for MGDEAD for the five towns are not directly observable. However, assuming that hunters from the same origin town have different preferences with respect to q and s, then

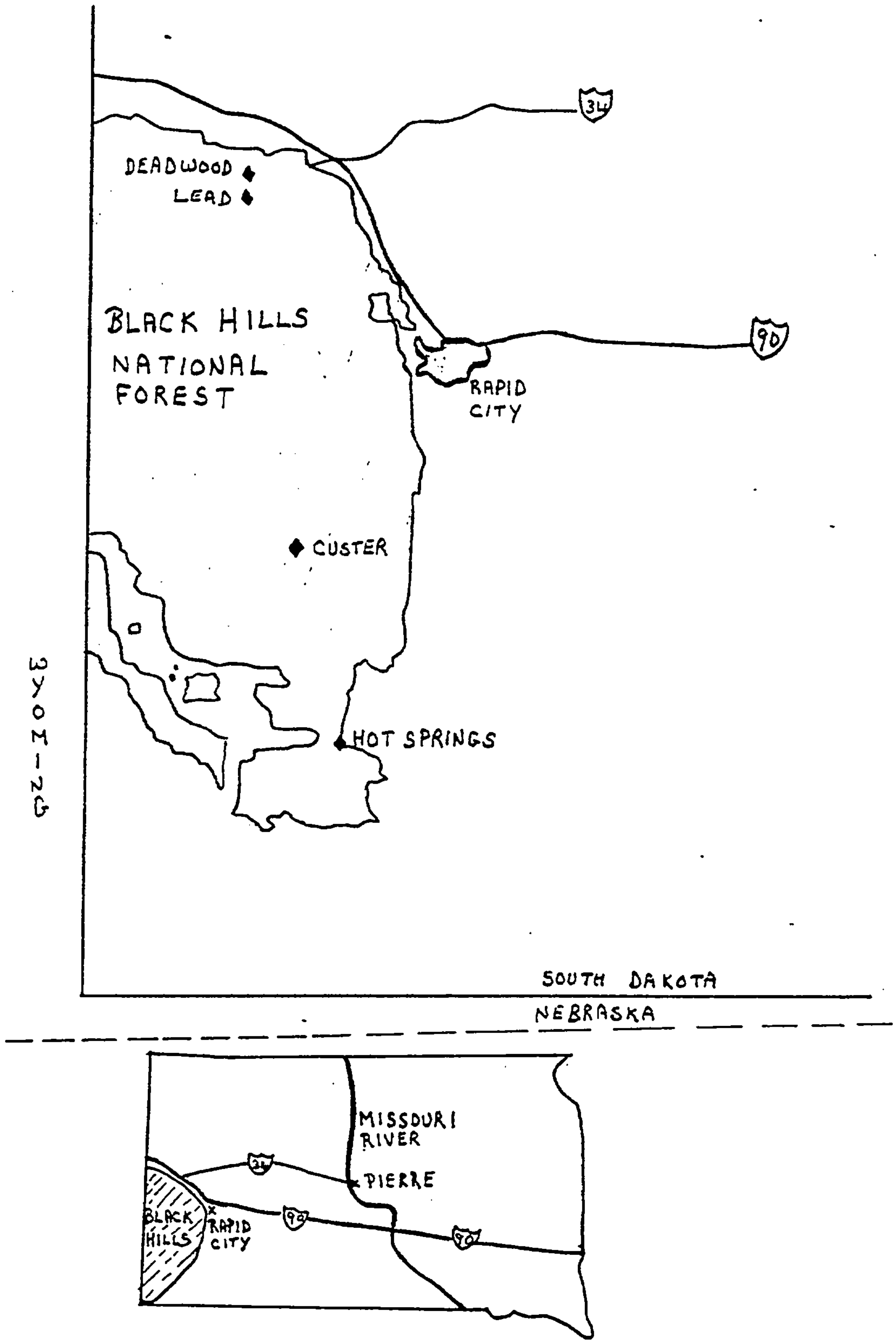

FIGURE 1. THE BLACK HILLS NATIONAL FOREST IN SOUTH DAKOTA

their different demands will trace out the total cost curve for MGDEAD from that origin. These total cost curves were estimated for each down, both using all observations and excluding the outlying observations mentioned above.[7]

Using both sets of observations, for each town the total costs of hunting for the season were regressed on the levels of MGDEAD and HEIGHT, and on a distance variable designed to represent h (DISTANCE). The latter was intended to distinguish between the many one-day visits case and the one long visit case. These predictor variables were used in linear and non-linear (cross-product) forms. Table 1(a) gives one the better fitting total cost equations for each of the five towns, using the complete data set. The equations in Table 1(b) were estimated using the constrained data set (excluding observations with $n > 15$).

The marginal cost of MGDEAD for each town was calculated by taking the partial derivative with respect to MGDEAD. Marginal cost estimates derived from the equations in Tables 1(a) and 1(b) are presented in Tables 2(a) and 2(b). Since these marginal cost estimates for MGDEAD do not vary with the level of MGDEAD, they can be used as prices in the demand function for MGDEAD, as long as HEIGHT is exogenous. Since the marginal cost price for MGDEAD for the consumer from Lead-Deadwood is zero, the fact that Lead-Deadwood deviates from the fixed n assumption does not cause the marginal cost estimate to deviate from what it would be were the assumption met. Both linear and semilog versions of the demand functions are estimated. Weighted versions (to correct for heteroscedasticity) are also estimated. These are shown in Tables 3(a) and 3(b).

TABLE 1(a). ESTIMATES OF THE TOTAL COST RELATIONSHIP

	RAPID CITY	STURGIS	CUSTER	HOT SPRINGS	LEAD-DEADWOOD
Dependent Variable	Total Cost	Total Cost	Total Cost	Total Cost	Total Cost
INTERCEPT	25.26 (8.01)**	59.24 (29.94)	-47.60 (79.66)	135.57 (86.74)	34.13 (25.98)
HEIGHT	0.12 (0.02)**		-0.13 (0.25)		0.11 (0.05)**
MGDEAD	0.041 (0.018)**	-0.033 (0.065)	0.25 (0.08)**	-0.44 (0.31)	-0.0053 (0.030)
DISTANCE	0.16 (0.03)**	0.031 (0.18)			
DHEIGHT	0.84×10^{-4} (0.55×10^{-5})				
DMGDEAD		0.00060 (0.00050)			
OPEN		0.74×10^{-3}) (0.24×10^{-3})**		0.0019 (0.00021)**	
DOPEN		-2.15×10^{-6} (9.03×10^{-7})**			
STAY				-93.18 (132.04)	83.70 81.1
POPEN					
PMGDEAD				0.12 (0.40)	0.019 (0.14)
SQUARE	0.54×10^{-4} (0.18×10^{-4})**		0.00045 (0.00015)**		
R^2	0.53	0.44	0.75	0.76	0.23
Adjusted R^2	0.52	0.37	0.73	0.72	0.09
F	60.11	5.98	32.11	20.13	1.63
L	-1,320.1	-202.4	-174.1	-130.3	-127.6
N	276	44	36	31	27

Where: HEIGHT = the average elevation of hunting sites chosen minus 4,500 ft. (1,371.6 m).
MGDEAD = the forage generated by the average basal area per acre of ponderosa pine at the hunting sites visited, multiplied by the average number of dead trees per acre. The latter is a proxy for the probability of forage being in small openings (less than 10 acres [4.0 ha]).
OPEN = HEIGHT x MGDEAD.
DISTANCE = distance from the origin town to the closest point in the Black Hills National Forest.
DHEIGHT = DISTANCE x HEIGHT.
DMGDEAD = DISTANCE x MGDEAD.
DOPEN = DISTANCE x OPEN.
STAY = whether any trips were overnight trips.
PHEIGHT = STAY x HEIGHT.
POPEN = STAY x OPEN.
PMGDEAD = STAY x MGDEAD.
SQUARE = HEIGHT x HEIGHT.
Bracketed numbers are standard errors.
**Indicates significance at 0.05 level (two-tailed test).

TABLE 1(b). ESTIMATES OF THE TOTAL COST RELATIONSHIP - CONSTRAINED DATA SET

	RAPID CITY	STURGIS	CUSTER	HOT SPRINGS	LEAD-DEADWOOD
Dependent Variable	Total Cost	Total Cost	Total Cost	Total Cost	Total Cost
INTERCEPT	25.26 (8.01)**	42.44 (23.41)	-13.17 (56.15)	225.35 (117.39)	34.13 (25.98)
HEIGHT	0.12 (0.02)**		-0.12 (0.26)		0.11 (0.05)**
MGDEAD	0.041 (0.018)**	0.005 (0.05)	0.17 (0.08)**	-0.77 (0.44)	-0.0053 (0.030)
DISTANCE	0.16 (0.03)**	0.08 (0.14)			
DHEIGHT	0.84×10^{-4} (0.55×10^{-5})				
DMGDEAD		0.00048 (0.00039)			
OPEN		0.00050 (0.00019)**		0.0019 (0.00052)**	
DOPEN		-1.31×10^{-6} (7.16×10^{-7})			
STAY				-238.16 (153.32)	83.70 81.1
POPEN				-0.0014 (0.00083)	
PMGDEAD				0.80 (0.54)	0.019 (0.14)
SQUARE	0.54×10^{-4} (0.18×10^{-4})**		0.00032 (0.00026)		
R^2	0.53	0.56	0.43	0.39	0.23
Adjusted R^2	0.52	0.51	0.36	0.25	0.09
F	60.11	9.57	6.16	2.91	1.63
L	-1,320.1	-186.8	-127.9	-119.9	-127.6
N	276	43	28	29	27

Where: HEIGHT = the average elevation of hunting sites chosen minus 4,500 ft. (1,371.6 m).
MGDEAD = the forage generated by the average basal area per acre of ponderosa pine at the hunting sites visited, multiplied by the average number of dead trees per acre. The latter is a proxy for the probability of forage being in small openings (less than 10 acres [4.0 ha]).
OPEN = HEIGHT x MGDEAD.
DISTANCE = distance from the origin town to the closest point in the Black Hills National Forest.
DHEIGHT = DISTANCE x HEIGHT.
DMGDEAD = DISTANCE x MGDEAD.
DOPEN = DISTANCE x OPEN.
STAY = whether any trips were overnight trips.
PHEIGHT = STAY x HEIGHT.
POPEN = STAY x OPEN.
PMGDEAD = STAY x MGDEAD.
SQUARE = HEIGHT x HEIGHT.
Bracketed numbers are standard errors.
**Indicates significance at 0.05 level (two-tailed test).

TABLE 2(a). MARGINAL COST ESTIMATES FOR MGDEAD

Rapid City	0.041
Sturgis	$(0.74 \times 10^{-3} - [0.22 \times 10^{-5} \times \text{DISTANCE}])\text{HEIGHT}$
Custer	0.25
Hot Springs	$0.0019 \times \text{HEIGHT}$
Lead-Deadwood	0

TABLE 2(b). MARGINAL COST ESTIMATES FOR MGDEAD - CONSTRAINED DATA SET

Rapid City	0.041
Sturgis	$(0.50 \times 10^{-3} - [0.13 \times 10^{-5} \times \text{DISTANCE}])\text{HEIGHT}$
Custer	0.17
Hot Springs	$0.0019 \times \text{HEIGHT}$
Lead-Deadwood	0

TABLE 3(a). DEMAND CURVES FOR MGDEAD USING PRICEH

	Linear Unweighted	Linear Weighted	Semilog Unweighted	Semilog Weighted	Linear With Instrument
Dependent Variable	MGDEAD	MGDEAD	LOG (MGDEAD)	LOG (MGDEAD)	MGDEAD
INTERCEPT	303.38 (27.88)**	295.38 (24.90)**	5.69 (0.05)**	5.67 (0.05)**	387.67 (34.56)**
HEIGHT	0.34 (0.04)**	0.33 (0.03)**	0.64×10^{-3} (0.73×10^{-4})**	0.62×10^{-3} (0.71×10^{-4})**	
PRICEH	-324.72 (122.25)**	-215.84 (109.70)**	-0.565 (0.236)**	-0.420 (0.22)**	-353.02 (264.65)
ANTERLESS	10.24 (17.59)	16.49 (15.76)	0.08 (0.03)	0.015 (0.03)	-39.47 (20.72)
INCOME	-0.09 (0.10)	-0.045 (0.09)	-0.33×10^{-4} (0.20×10^{-3})	0.89×10^{-5} (0.18×10^{-3})	-0.06 (0.12)
YRSHUNT	2.21 (0.76)**	1.49 (0.69)**	0.005 (0.001)**	0.003 (0.001)**	2.79 (0.94)**
R^2	0.17		0.16		0.04
F	20.46		19.19		4.39
N	520	520	520	520	435

Where: MGDEAD = the forage generated by the average basal area per acre of ponderosa pine at the hunting sites visited, multiplied by the average number of dead trees per acre. The latter is a proxy for the probability of forage being in small openings (less than 10 acres [4.0 ha]).

HEIGHT = the average elevation of hunting sites chosen minus 4,500 feet (1,371.6 m).

PRICEH = 0.041 for Rapid City, [0.00074 - (0.0000022 x DISTANCE)] x HEIGHT for Sturgis, 0.25 for Custer, 0.0019 x HEIGHT for Hot Springs, and zero for Lead-Deadwood.

ANTERLESS = 1 if the hunter applied for anterless license, 0 if he did not.

INCOME = the hunter's income level in hundreds of dollars.

YRSHUNT = the number of years the hunter has hunted.

Bracketed numbers are standard errors.

**Indicates significance at the 0.05 level (two-tailed test).

TABLE 3(b). DEMAND CURVES FOR MGDEAD USING PRICEJ - CONSTRAINED DATA SET

	Linear Unweighted	Linear Weighted	Semilog Unweighted	Semilog Weighted	Linear With Instrument
Dependent Variable	MGDEAD	MGDEAD	LOG (MGDEAD)	LOG (MGDEAD)	MGDEAD
INTERCEPT	316.43 (29.23)**	296.93 (26.17)**	5.69 (0.06)**	5.67 (0.05)**	418.98 (37.40)**
HEIGHT	0.35 (0.0039)**	0.34 (0.04)**	0.00064 (0.00009)**	0.00064 (0.00007)**	
PRICEJ	-522.63 (211.82)**	-277.61 (192.40)	-0.92 (0.41)**	-0.59 (0.39)	-1248.86 (447.41)**
ANTERLESS	10.38 (17.74)	17.30 (15.82)	0.09 (0.03)	0.17 (0.033)	-39.41 (20.68)
INCOME	-0.94 (0.10)	-0.05 (0.09)	-0.00003 (0.00020)	0.7×10^{-5} (0.19×10^{-3})	-0.04 (0.12)
YRSHUNT	2.22 (0.77)**	1.46 (0.70)**	0.004 (0.0014)**	0.0033 (0.0014)**	2.85 (0.94)
R^2	0.17		0.16		0.05
F	20.66		19.09		5.87
N	510	510	510		422

Where: MGDEAD = the forage generated by the average basal area per acre of ponderosa pine at the hunting sites visited, multiplied by the average number of dead trees per acre. The latter is a proxy for the probability of forage being in small openings (less than 10 acres [4.0 ha]).

HEIGHT = the average elevation of hunting sites chosen minus 4,500 feet (1,371.6 m).

PRICEH = 0.041 for Rapid City, [0.00050 - (0.0000013 x DISTANCE)] x HEIGHT for Sturgis, 0.17 for Custer, 0.0019 x HEIGHT for Hot Springs, and zero for Lead-Deadwood.

ANTERLESS = 1 if the hunter applied for anterless license, 0 if he did not.

INCOME = the hunter's income level in hundreds of dollars.

YRSHUNT = the number of years the hunter has hunted.

Bracketed numbers are standard errors.

**Indicates significance at the 0.05 level (two-tailed test).

When HEIGHT is not treated as exogenous, the instrument ANTERLESS (if the hunter applied for an anterless hunting permit) was used in its place. ANTERLESS was the one socioeconomic variable which exhibited a much higher correlation with HEIGHT ($r = -0.24$) than with MGDEAD ($r = -0.06$). In using this instrument, observations were included only for towns whose marginal cost price for MGDEAD did not depend upon HEIGHT. Only the linear unweighted version of the demand curve was estimated using ANTERLESS as the instrument for HEIGHT. The results are shown in the rightmost column of Tables 3(a) and 3(b).

Now enough information has been generated to obtain measures of the consumer's surplus change that would occur due to some management action. It has been noted that the marginal cost price for MGDEAD for the Lead-Deadwood consumer is zero. This is because of the easy accessibility to an area exhibiting high levels of MGDEAD. One question that might be asked involves determination of the additional consumer's surplus that would be obtained by a hunter from another town were the characteristic made equally easily available to him at the same level. Now we will calculate the consumer's surplus benefit that a hunter from Custer would obtain were he to have the same marginal cost for MGDEAD as a hunter from Lead-Deadwood, with the marginal cost of HEIGHT remaining constant, is analyzed here.

This is not an abstract example. The Norbeck timber sale is scheduled to take place on forest compartment 302. This compartment is roughly the same distance from Custer, as compartment 703, currently exhibiting higher MGDEAD values, is from Lead-Deadwood. A main purpose of the sale in compartment 302 is to increase deer habitat. This will be done by reducing average basal area per acre to around 70 and

TABLE 4. VEGETATION CHARACTERISTICS BY SUBCOMPARTMENT

Town	Subcompartment	Average Basal Area Per Acre (per ha.)		Pounds Per Acre of Forage* (kg. per ha.)	
		Existing	Post-Norbeck	Existing	Post-Norbeck
Custer	30204	161	57	56	494
	30206	116	64	143	427
	30207	146	101	76	196
	30208	146	39	76	721
	30209	147	80	75	305
	30210	124	86	121	269
Lead-Deadwood	70301	46	n.a.	620	n.a.
	70302	85	n.a.	275	n.a.
	70303	82	n.a.	292	n.a.
	70304	76	n.a.	332	n.a.
	70305	98	n.a.	208	n.a.
	70307	66	n.a.	409	n.a.

*Calculated from forage equation in Pase and Hurd (1957).
n.a. = not applicable.

distributing the cutting in a pattern of small openings. Table 4 shows the average basal area per acre and forage per acre for compartment 703. This is compared with the current situation in 302 and projected the post-sale situation.

First consider the current situation in subcompartments in the vicinity of Custer, and in the vicinity of Lead-Deadwood. Table 4 shows the values of the key variables for the compartments.

The result of the Norbeck sale in terms of our model is that the marginal cost of MGDEAD to a hunter from Custer would drop to that of a hunter from Lead-Deadwood, zero. Tables 5(a) and 5(b) give consumer's surplus changes for a hunter who was hunting prior to the marginal cost change. Consumer's surplus changes are calculated for the five alternative demand equations of Tables 3(a) and 3(b). Based on Table 5(a), the consumer's surplus gain for a Custer hunter is in the $99 to $124 range. In 1980 there were 844 hunters from Custer.[8] This would have meant aggregate benefits for Custer hunters in the neighborhood of $94,000, or $15 per member of the population of Custer County.

In fact the number of hunters may change, although it is not possible with current data to estimate the extent of the change. If the decrease in the marginal cost of MGDEAD results in new hunters, these new hunters may well obtain greater consumer's surplus changes than existing hunters. For these new hunters the best consumer's surplus estimate we can obtain is the full consumer's surplus after the marginal cost change net of fixed costs. In the case of Custer this amount is the sum of the $99 to $124 change and the original total consumer's surplus amount, minus fixed costs. The maximum this could be is $243 to

$393 per new hunter. The present participation rate for Custer County is 0.14, higher than any other county. If this were to increase to 0.15 there would be about 56 new hunters who would in the aggregate obtain an annual increase in consumer's surplus of $13,600 to $22,000. Added to the $94,000 for existing hunters this gives a total of between $107,600 to $116,000. Using Table 5(b) amounts, the comparable range would be between $69,800 and $77,000.

Table 4 also provides estimates for a similar management change that would produce a vegetative pattern, similar to that in the vicinity of Lead-Deadwood, in the vicinity of each of the other towns. One can note that smaller benefits accrue to hunters from other towns. Part of the reason for this is the relatively large cost reductions experienced by Custer hunters. Hunters from Hot Springs and Custer currently have the greatest marginal costs for MGDEAD. Substantial reductions in cost can be expected to yield substantial benefits. Another part of the reason is that hunters from Custer tend to choose higher elevations than hunters from other towns except Lead-Deadwood. As the elevation variable (HEIGHT) is a demand shift variable, this results in higher consumer's surplus estimates.

The $99 to $124 benefit range for a.Custer hunter is for one hunting season. If a management policy were instituted to maintain the situation that produced these benefits, rather than to maintain the existing situation, then it would be possible to evaluate it by allowing benefits to occur annually and calculating the present value of benefits from the policy. For example, if the new vegetative pattern resulting from harvesting in 302 were to be maintained for 20 years and annual

TABLE 5(a). CONSUMER'S SURPLUS CHANGES - VERSION 1

Town	Linear Unweighted	Linear Weighted	Semilog Unweighted	Semilog Weighted	Linear With Instrument
Rapid City	16	16	15	14	16
Sturgis	14	15	16	16	
Custer	113	124	103	99	93
Hot Springs	84	120	76	51	
Lead-Deadwood	0	0	0	0	0

TABLE 5(b). CONSUMER'S SURPLUS CHANGES - VERSION 1 - CONSTRAINED DATA SET

Town	Linear Unweighted	Linear Weighted	Semilog Unweighted	Semilog Weighted	Linear With Instrument
Rapid City	16	16	14	14	16
Sturgis	11	11	9	9	
Custer	71	78	63	63	82
Hot Springs	50	71	49	51	
Lead-Deadwood	0	0	0	0	0

TABLE 5(c). CONSUMER'S SURPLUS CHARGES - VERSION 2 - CONSTRAINED DATA SET

Town	Linear Unweighted	Linear Weighted	Semilog Unweighted	Semilog Weighted
Rapid City	20	20	17	17
Sturgis	14	14	12	12
Custer	86	94	77	78
Hot Springs	60	80	64	62
Lead-Deadwood	0	0	0	0

benefits of $112 per hunter were to accrue at a 6 percent discount rate, then the present value of discounted benefits would be $1,300 per hunter. If the number of hunters did not change this would be $1,097,000 in the aggregate. Allowing the participation rate to increase by one percentage point would bring this amount to around $1,300,000. Using Table 5(b) values this is reduced to around $800,000.

For purposes of sensitivity analysis it is useful to consider what the consumer's surplus change would have been had the second version of the hedonic model ($Q = nq$) been used. If the constrained observation set is used, there will be no differences in the marginal cost price estimates. However, it is now possible to take account of the fact that $n = 8$ for Lead-Deadwood, as compared to $n = 5$ for the other towns. If n is to be treated as constant along the demand curve for q, the observed q for Lead-Deadwood must be replaced by 8/5 q for the consumer's surplus change calculation. This results in the consumer's surplus change calculations in Table 5(c). Using the mean of these consumer's surplus amounts the benefit estimate would be $950,000.

Overall, the sensitivity testing produced a range of individual consumer's surplus change amounts of $62 to $124, and a range of total benefit estimates of $800,000 to $1,300,000. The Version 2 results based on the constrained data set, are roughly in the middle of the range and are judged to be the most reasonable estimates.

V. CONCLUSIONS

The hedonic model applied in the Black Hills case study is one of the specific models than can be derived from the general household production function model. The methodology used here has some similarities to those used by McConnell (1979) and Mendelsohn (1983).

In section I four issues that arise in going from the general model to the specific model were mentioned; identifiability, weak complementarity, path-independence and compensated demand curve approximation. In section II these issues were discussed with respect to a number of specific models, including the hedonic one. However, the identifying restrictions and other assumptions used here are not the only possible ones.

It is clear that at least some subset of the demand and cost functions must be identifiable, and that this does involve certain restrictions. However, the range of possibilities for identification have not been well investigated. The form of the cost function is one. area where further investigation would be useful. Here exogenous variation was introduced into the cost function through specifying different origins with the same level of $\mathbf{h}_j$ but different costs of obtaining s and q. Assuming that s and q are not perfectly jointly supplied, and that the set of exogenous demand shifters affecting q is not identical to the set affecting s, then the marginal cost curves for q and s can be identified. If the change in the marginal cost of q is to be simulated by exogenous variation across origin towns, then it is also necessary that there be variation across towns in the marginal cost of q that is independent of variation in the marginal cost of s. Are such assumptions realistic, and if so, in which cases?

Without sufficient variation in recreationists' preferences, the estimation of the total cost function and the marginal cost curves is not possible. Certainly if all consumers were identical it would not be possible to estimate any of the cost curves. In general, this approach is limited by the number of sites actually visited by consumers from a given origin. An alternative would be, not to use observations on recreationists' actual visits, but to estimate the cost curves based on the sites available at a given origin. This would involve a complete enumeration of sites and the levels of the characteristics available at each. However, with such an approach, it would be possible to use a linear programming model to find the least cost ways of obtaining different levels of the characteristics. This would give the information required for the marginal cost curve. In some cases characteristics may be perfectly jointly supplied, but this will become apparent in the process determining the least cost solutions.

Identification of the demand curve for the characteristic of concern can also be problematical. Although it is clear that there must be exogenous variation in the marginal cost of q, if the benefits from a shift in that marginal cost are to be estimated, further restrictions may be required to estimate the demand curve for q. If the demand prices for other characteristics, or the characteristics themselves, are exogenous they will help identify the demand equation for q. If neither the other characteristics nor their prices are exogenous, then instruments for the endogenous variables are required. These may be either demand or supply related. In this study ANTERLESS (whether or not a hunter had applied for a permit to hunt anterless deer) was used as an instrument for HEIGHT in the demand equation for MGDEAD. In his recreational fishing study McConnell (1981) used "years of experience" as a shift variable in the demand equation for quantity of fishing days, and "number of rod and reel combinations owned" as a shift variable in the demand equation for the level of quality demanded. The potential for identification through the selective exclusion of demand shifters has not been fully explored. Since there are a number of studies on attitudes, preferences and motivations of groups of recreationists like hunters and fishermen, it may well be possible to get some ideas for selective exclusion from these studies, and to test them in econometric models.

Restrictions on the form of the utility function can also be used in identification. If it is to be assumed that every quantity unit consumed by a given consumer has the same levels of the characteristics, then, if the characteristic choices are taken separately for each quantity unit, these choices must be independent of the total quantity level consumed. This implies that the choice of the characteristic levels must be independent of the choice of n, and that these characteristic levels can be taken as predetermined in the demand curve for n. In some cases it can also be assumed that n is chosen independently of the characteristics, and n can be treated as predetermined, or fixed, in the demand and marginal cost curves for the characteristics.

In general, it will not be observed that each quantity unit consumed by a given consumer has the same characteristics levels. It may be assumed that this is the result of random variation stemming from imperfect information. If this is true the mean characteristic levels can be treated as the intended characteristic level choices.

Another possible reason for different site choices is that the utility function is different for different quantity units. For example, on some days a hunter may place a high priority on bagging game. On other days he may be more interested in the scenery. The problem is that it is virtually impossible to distinguish different between quantity units with a bag emphasis and quantity units with a scenery emphasis. Suppose the utility function is (28):

$$U(x) + n_1 U(q_1) + n_2 U(s_2) \qquad (28)$$

where: n_1 = bag type quantity units;
n_2 = scenery type quantity units.

Now suppose the cost function is (29):

$$x + n_1[h + K(q_1) + q_1 J(s_1)] + n_2[h + K(q_2) + q_2 J(s_2)] \qquad (29)$$

The first order conditions for q_1, s_1, q_2 and s_2 will be:

$$U_{q1}/U_x = K_{q1} + J(s_1) \qquad (30)$$

$$0 = q_1 J_{s1}$$

$$0 = K_{q2} + J(s_2)$$

$$U_{s2}/U_x = q_2 J_{s2}$$

Only q_1 will be consumed for bag type quantity units, and only s_2 for scenery type units. If n_1 and n_2 cannot be identified, then the best that can be done is to average the q and s levels over all n. Since $s_1 = 0$ and $q_2 = 0$, the conditions in (30) are simplified to:

$$U_{q1}/U_x = K_{q1} \qquad (31)$$

$$U_{s2}/U_x = 0$$

This implies that the effective cost function is:

$$x + n_1[h + K(q_1)] + n_2[h] \qquad (32)$$

Using $\bar{q} = (q_1 n_1)/n$ and $\bar{s} = (s_2 n_2)/n$, (28) and (29) become

$$U(x) + n\, V(\bar{q}) + n\, V(\bar{s}), \qquad (33)$$

and

$$x + n[h + L(\bar{q})] \qquad (34)$$

where: $V(\bar{q}) = \dfrac{n_1\, U(q_1)}{n}$

$$V(\bar{s}) = \frac{n_2\, U(s_2)}{n}$$

$$L(\bar{q}) = \frac{n_1 K(q_1)}{n}$$

The first order conditions are:

$$V_q/U_x = L_q \qquad (35)$$

$$V_{\bar{s}}/U_x = 0$$

Although the model in (35) can be used to value shifts in K_q, it is worth noting that in this case the cost function would be more appropriately estimated using observations on sites visited. Using available sites and a linear programming approach to estimate the cost function will only work, if the specific site choices made are not obscured by averaging.

Another question of relevance in identifying the relevant cost and demand functions, is how the quality characteristics are related to the quantity unit in the utility function. Related to this is the question of what the appropriate quantity unit is, Particularly with characteristics such as the probability of bagging game, it is clear that the characteristic must be defined for a fixed time period, such as an hour, or day of specified length. In this context, using quantity units of different time lengths makes no sense. Visits can be used as the quantity unit, only if they are of the same length, or if the level of the characteristic consumed per quantity unit is adjusted to reflect visit length.

In this paper we have indicated two forms of the utility function which might incorporate this "repackaging" approach. In one case the utility derived from the characteristic q, was multiplied by the number of quantity units, n. In the other, the level of the characteristic consumed is Q = nq, and total utility is a function of nq. These two models can lead to different results. In general, the relationship between quantity units and quality characteristics has not been well investigated.

Related to the question of the appropriate quantity unit is the question of time costs. Two of the findings in this study were that visit length tends to increase with travel distance and that weekdays and weekend days are not viewed by recreationists as having the same opportunity costs of time. First of all it was observed that as distance from the Black Hills National Forest increased hunters tended to switch from taking many one-day visits to taking one long visit. Only a small set of hunters at intermediate distances tended to take a number of visits of different lengths. It would appear that another one-day visit is a perfect substitute for another day added to an existing visit, and the choice of which way to take an additional day is based upon the relative cost of the two alternatives. It is also implied that, for any hunter to take many one-day visits, it must be true either that there are virtually zero travel costs to the site, or that the opportunity cost of time increases with visit length. It is at least in part the latter. Since hunters are more likely to stay overnight if the next day is a weekend or holiday than if it is a weekday, it appears that a higher opportunity cost is attached to weekday time than to weekend time.

By looking at the choice of how to take another day (stay overnight or go home and come back another time), it was possible to determine the relative opportunity cost of time associated with a weekday versus a weekend day or a holiday. The difference was in the neighborhood of $26 per day. Since longer visits are more likely to involve weekdays than are shorter visits, on the average the opportunity cost of time for a one-day visit will be less than for a day within a longer visit, and on average the opportunity cost of a day will tend to increase with distance from the site visited. Since time costs can be important elements of the costs associated with recreation visits, it would be useful to further explore the generality of this perfect substitutes case.

Weak-complementarity also involves restrictions on the cost and utility functions and, can be very useful in limiting the extent of the additional restrictions required for identification. Traditionally, weak-complementarity has been taken to mean that the marginal willingness to pay for q is zero when n is zero. However, there are many other ways in which weak-complementarity can be used and it can apply to the cost as well as to the demand side of the picture. This study used the weak-complementarity assumption to imply that when q = 0, the marginal willingness to pay for n is zero. The justification is evidence provided by psychologists' studies, showing that "bagging game" is a necessary part of the hunting experience. On the cost side, this weak-complementarity assumption is harder to justify. There can well be a fixed cost such that even sites with zero probability of bagging game are only available at a positive cost to hunters.

The conditions which allow path-independence and compensated demand curve approximation are also important considerations. In the models estimated here, path-independence is most often not an important consideration. If n and s are exogenous then there is only one path. If s is exogenous, and the Q = nq repackaging model is used, then the path independence condition is automatically met because it must be true that $g_{1n} = g_{2q} = g_Q$ where $g_1(n,q,x)$ is the inverse demand function for q, $g_2(n,q,x)$, the inverse demand function for n, and $g_Q(Q,X)$ is the inverse demand function for Q. If s is not exogenous the conditions must also include $g_{QS} = g_{3Q}$ where $g_3(Q,S,X)$ is the inverse demand curve for s.

When n and s are exogenous the only income effect, which can affect the degree to which the Marshallian demand curve approximates the compensated demand curve, is that on q. In the Black Hills case that income effect turned out to be zero. However, this need not always be the case. The size of the income effect should always be investigated. If they are not small an approach similar to that of Hausman (1981) should be used to derive the compensated demand curve.

Finally, another questions which deserves further attention, is that of whether or not individual observations are sufficient to estimate the benefits from a decrease in the marginal cost of q to some recreationists. There are two questions involved. The first is whether truncation bias exists. That is, do nonparticipants tend to consume different levels of n, q or s than do participants? If they do then demand curves based only on participants will reflect both the effect of price on quantity, and the effect of the truncation.

The second question is whether consumer's surplus changes can be measured using only data on participants. It has been shown earlier in the paper that benefits to current users can be measured with such data. In many cases these will constitute most of the benefits. However, there is still the possibility that the increased availability of the quality characteristic, q, will increase the expected use level creating additional benefits. To measure this we do need to know the extent to which the probability of participation is increased by the increased availability of q. In the Black Hills study probability of participation estimates were available only by county, and this made it impossible to know how the probability of participation would change. It was simply assumed that the probability would change by one percent. It would, however, be useful to test the effect of a change in a quality characteristic level, or a change in the marginal cost of a characteristic, on the probability of participation for a given origin. This necessitates that actual numbers of visitors to a site from an origin be known as well as the population level of the origin zone.

What is clear from this study is that the general household production function model can be used to derive a number of more specific models that can be very useful in estimating the value of increased availability of resource services to recreationists. This study has estimated one such model, with some consideration given to how varying the assumptions to obtain a slightly different model affects the results obtained. However, it is quite clear that there are a number of areas in which further research is necessary. Most of these have to do with the specific assumptions that are most reasonable in applying the general methodology. Further research should both test the generalizability of the assumptions used in this study, explore other assumptions that might be more reasonable in other cases, and to make comparisons between models derived using different sets of assumptions.

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NOTES

[1]Based on extensive literature searches. Both Boyce (1977) and Thomas (1979) have developed relationships which express the suitability of an area for wildlife habitat in terms of its land and vegetative characteristics. For example, Boyce, in studying deer habitat in hardwood forests in the southern Appalachians, found that forage availability and the size of openings permitting utilization of forage were key factors. Thomas' work focusing on the Blue Mountains of Oregon and Washington provides similar findings.

[2]In the "Human Dimensions in Wildlife" session at the Thirty-Eighth North American Wildlife and Natural Resources Conference, all three papers on the topic (Potter, Hendee and Clark [1973]; More [1973]; and Stankey and Lucas [1973]) stressed this point. The paper by More uses a quotation from the Spanish philosopher Ortega y Gasset (1972) to illustrate the role of success in hunting. "One does not hunt in order to kill; on the contrary, one kills in order to have hunted."

[3]Both of these models assume that all quantity units consumed by one consumer exhibit the same q and s choices. That is, all days are consumed at the same site. This is not what is in fact observed. One consumer may go to a number of different sites. This could be for a number of reasons. The consumer's utility function and/or cost function could be such that he specializes his days. Some days may be specialized in s, and some in q. Alternatively it might be the case that variation in the q and s choices is caused by a demand for variety that introduces a small random element into a consumer's site choice. The latter assumption is used here, and the attribute or characteristic levels consumed are assumed to be the average levels over all days consumed.

[4]The calculation was based on work by Pase and Hurd (1957).

log (forage in lbs. per acre) = 3.2260 - 0.00936 (basal area of ponderosa pine in square feet per acre).

Several adjustments were made based on work done in the Black Hills National Forest. See "Forest-Browse Coefficient Documentation," mimeo provided by Leon Fager, Wildlife Biologist, Black Hills National Forest.

[5]The proxy variable for openings was the average number of dead trees per acre in the compartment. It was chosen because areas high in this variable appeared to be attractive to hunters and to have high success rates. After some discussions with Black Hills Forest personnel and people from the South Dakota Department of Game, Fish and Parks, it was hypothesized that the reason for this was that the high numbers of dead trees were due to mountain pine beetle infestation. The combined result of the infestation and the management of it created small openings, as trees were removed from around the infested tree or trees.

[6]Diagnostic statistics proposed by Belsley, Kuh and Welsch (1980) were used to select influential observations. Three statistics were used RSTUDENT, DFFITS and DFBETAS. The critical values used to select influential observations. Observations with the largest number of days (more than 15) were found to be most influential. Although the fact that they are found to be influential does not itself justify excluding them, the fact that these few observations (10) caused the fixed n assumption to be violated for Custer at least justifies excluding them for purposes of sensitivity analysis.

[7]Total costs included all travel costs at 8 cents per mile (AAA variable cost estimate for 1980) plus time costs. The calculation of time costs made use of the fact that in the Black Hills data it was

observed that hunters living close to the site, take a number of day visits, while hunters living further away take one long visit. For each day a hunter is observed visiting the Black Hills (not including the last day), there is a probability (P) of going home and returning on another day and a probability (1 - P) of staying overnight. Assuming the two alternative ways of consuming another day provide the same utility, the choice will be based on relative costs. When the relative costs are equals, both probabilities will be 0.5. The relative costs include both time and money costs. The money costs are largely travel. Although one might suppose lodging costs to be a factor, lodging costs were in fact very small. What appeared to be considerably more important was whether or not the next day was a weekday. This implied a difference in the time costs associated with weekdays versus weekends or holidays. For any given hunter the probabilities will be 0.5 when

$$TC + t_1 = t_2 \quad (1)$$

where: TC is the money cost of travel;
t_1 is the time cost of the next day when the hunter goes home and comes back;
t_2 is the time cost of the next day when the hunter stays over.

Assuming time is only available in blocks of one day, that no trip to the site and back takes more than one day, and that time not spent hunting has a marginal utility of zero, it is possible to vary TC while holding t_1 and t_2 constant, to see where the equality holds. This was done using a logit model. The dependent variable is log(P/1 - P), which equals zero when P = (1 - P) = 0.5. The model estimated was:

$$\log(P/1 - P) = a + bD = cH \quad (2)$$

where: a, b and c are parameters to be estimated;
D is the one-way distance from home to site;
H = 1 if the next day is a weekend day or a holiday;
H = 0 if the next day is a weekday.

The result was:

$$\log(P/1 - P) = 1.55 - 0.0097D - 1.55H \qquad (3)$$

Setting the left-hand side to zero, when H = 1, D = 0. That is, if the next day is a weekend day or a holiday, the hunter would only return home if the distance was zero This implies from (1) that TC = 0 and $t_1 = t_2$. If H = 0 , D = 160 or 320 miles round trip. At 8 cents per mile, TC = \$26. Now (1) gives $t_1 + 26 = t_2$. Together these imply that weekdays cost \$26 more than weekend or holidays. There is no estimate for the time cost of a weekend, but if we conservatively estimate it at zero, the time cost for any given day is

$$P_H \cdot 0 + (1 - P_H) \cdot 26 \qquad (4)$$

where: P_H is the probability of the next day being a holiday or weekend day;
$1 - P_H$ is the probability of the next day being a **weekday.**

The total time cost over a season is

$$[P_H \cdot 0 + (1 - P_H) \cdot 26]n$$

where: n is the total number of days hunted.

There was no actual estimate of the number of hunters from Custer. However, 270 hunters returned report cards from Custer County. The average return rate of 32 percent, which seems to be fairly constant across the counties for which both the number of hunters and report cards are available, would have meant 844 hunters from the county.

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Modelling the Demand for Outdoor Recreation

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ABSTRACT

This paper critically reviews several of the new methodologies developed in the last ten years to model the demand for recreation. The purpose of the review is to assess which techniques are most appropriate for valuing (1) new sites and (2) changes to existing sites.

There are three competing approaches to modelling heterogeneous recreation sites: partitioning, hedonics, and index models. Partitioning involves grouping sites into small homogeneous sets and treating each set as a unique good and is best represented by multiple site travel cost models. Hedonics involves disaggregating goods into their component characteristics and modelling the prices and demands for the characteristics and is best represented in the recreation context by the hedonic travel cost method. The index models involve measuring the demand for a standard good and explaining variations in that demand across goods explicitly in terms of observable characteristics. Both generalized travel cost and discrete choice models are members of this last approach.

None of the approaches clearly dominate in all circumstances. For example, when valuing whole sites, the partitioning and index models appear best. Partitioning being preferred when there are a few discrete types of sites, discrete choice models being preferred when the relevant set of sites satisfy the independence of irrelevant alternative axiom, and generalized travel cost being preferred when there is a single site choice or no observable substitution across sites.

When valuing characteristics, each approach has special circumstances when it is most appropriate. Generalized travel cost is best when there is a single site to choose from. When there are only a handful of site types to choose from and the relevant characteristic is the distinguishing feature between two types of sites, multiple site travel cost is best. When there are multiple sites and independence of irrelevant alternatives is satisfied, the logit discrete choice models may be best. Otherwise, tire best available method to measure the value of characteristics is the hedonic travel cost method. This is especially evident when there are many sites and the relevant issue is a small change in characteristics at a single site.

Although there has been a great deal of high quality research concerning recreation demand modelling in the last ten years, there remains a need for additional work. All of the available techniques need refinement and additional development. Further, there is a need for more comparisons to establish the conditions under which each method is most appropriate.

MODELLING THE DEMAND FOR RECREATION

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INTRODUCTION

Beginning with the pathbreaking work of Marion Clawson [1959], economists have been trying to develop techniques to place a dollar value on outdoor recreation for over a quarter century. In the last ten years, this methodological development has turned into a virtual revolution as a multitude of state-of the-art approaches have sprung into existence. The primary achievement of this new breed of methodologies is their focus on modelling the heterogeneity of recreation opportunities. By explicitly recognizing the qualitative component of recreation sites, these new methodologies are suddenly capable of answering new and key policy questions. First, what is the net value of adding a new site with particular characteristics to an existing system of sites? Second, what is the value of changes in existing sites either through degradation or enhanced management?

Although the economic tools of supply and demand are invaluable to the study of resource allocation (microeconomics), these tools are based on the assumption of a homogeneous set of goods and services. All units of a good are assumed to be perfect substitutes both in production and value. Traditional economic analysis consequently must be modified to address heterogeneous goods and the issue of quality.

There are three basic approaches to handle the heterogeneity or quality component of goods in the economics literature at present. (1) The oldest approach (partitioning) is to segment the heterogeneous goods into fine enough categories that all the goods within each category can be considered the same (almost perfect substitutes). Each category is then treated as a separate good and traditional demand system models are applied to examine substitution amongst the categories. (2) The hedonic methodology treats goods as bundles of homogeneous characteristics. An implicit market in the characteristic world is assumed where individual characteristics have prices and underlying supply and demand curves. (3) The index approach, like the partitioning model, deals explicitly with choosing one good amongst many. However, like the hedonic model, the choice amongst goods is an explicit function of the physical characteristics Of the goods. Instead of a market for characteristics, though, this third approach falls back upon an exogenous index of attributes by which heterogeneous goods are cardinally ranked. Each of these three basic approaches have been applied with varying success to model recreation.

In this paper, the leading revealed preference techniques to value outdoor recreation are reviewed and assessed in terms of their ability to answer the two policy questions above. Some drawbacks such as incomplete data are common to every technique. The focus of this review, however, is upon the relative strengths and weaknesses of each approach. The special circumstances in which one technique is preferred or is invalid are identified whenever possible. The list of methodologies reviewed include: multiple site travel cost, generalized travel cost, discrete choice, hedonic travel cost, and gravity models. The paper is organized around the three basic approaches: partitioning, hedonics, and index models and concludes with a summary statement and recommendations for further research.

PARTITIONING

The oldest and perhaps most straightforward approach to handling a set of heterogeneous goods is to group similar members of the set into homogeneous categories. Since ail the remaining members within each category are alike, each category can be treated as a traditional homogeneous good and the familiar demand and supply tools of microeconomics can be applied. One advantage Of this approach is that both the theoretical and econometric tools are familiar and well developed so that application is straightforward. Another attractive component of this approach is that the substitution across categories is explicitly modelled so that the effect of introducing one type of site on other existing sites can be easily seen.

The first paper to apply the partitioning approach to recreation analysis is Burt and Brewer's [1972] analysis of the recreation value of lakes in Missouri. In this analysis, lakes were subdivided by natural versus manmade and by size. They found the demand for manmade lakes was more elastic than the demand for natural lakes suggesting the two types of lakes are not at all perfect substitutes. Another important application of the partitioning approach is the study by Cichetti, Fisher, and Smith [1976] of ski areas in California. These authors found considerable substitution amongst ski areas suggesting that the introduction of yet another site would significantly affect the demand for the existing set of sites.

These applications illustrate the strength of the partitioning approach, its theoretical and econometric soundness and its ability to reveal substitution amongst types of sites. However, the applications also illustrate the limitations of the partitioning approach. First the partitioning approach becomes cumbersome quickly as the number of categories multiply. For each category, there is another price and another demand equation. For example, with only three goods, the demand model can be written:

$$Q1 = F(P1, P2, P3, W) + e1$$

$$Q2 = F(P1, P2, P3, W) + e2$$

$$Q3 = F(P1, P2, P3, W) + e3$$

where Pi is the price of the closest member of type i, Qi is the visitation sate to site type i, W is a vector of individual demand shift variables, and ei is the error term in each equation. As the number of categories increases, each equation includes more prices and there are more equations until the number of parameters becomes overwhelming. Note that in both applications of this method, there are only six categories or types of sites..

A second issue concerns how to divide the distribution of sites into discrete types in the first place. When there is a single parameter of quality, the problem is simply trading Off between the number of categories to model and the homogeneity within each category. Obviously, the more categories, the more similar units can be within each category. Perhaps less obvious is where to make the divisions. In general, site divisions should be made to isolate the tails or extreme values of a distribution. For example, suppose the quality Z of sites is distributed lognormally and heterogeneity is captured by the variance of Z within each category. As shown in Mendelsohn [1984a], the first division should not be around the mean but rather much further down the tail of the distribution grouping most of the sites in one category and the extreme members of the distribution in the remaining category. Further divisions of the distribution also focus on the highly disparate tail.

The problem of division becomes even more complicated if there are several dimensions in which to distinguish sites. Without a predetermined index by which to weight each characteristic, there are many ways to group the sites all of which could potentially be valid. By trying different groupings, and reestimating the resulting equations, one can explore which categories are in fact distinct and which are really arbitrary divisions which have no meaning to the consumer. Only if each site is clearly unique, can an investigator easily avoid this multiple clustering problem.

The remaining limitations of the partitioning approach concern applications of the model to policy questions. The valuation of a new site can only be done if the new site belongs in one of the existing categories. There is no formal mechanism to make inferences about new sites which might fall between two or more existing types of sites. The inability of the approach to handle a large number of finely tuned categories exacerbates this problem as new sites must fall into one of only a few modelled types. If the analysis is designed to value specific type of new site, the attributes of this new site should be taken into account when designing the modelled site types. In this case, if the data permits it, priority should be given to including a site type which closely mirrors the new site.

The partitioning approach is perhaps even more limited in its ability to model changes to a site. Changes can be evaluated only if both the otherwise identical original site and modified site happen to be distinct modelled categories. For example, one could have modelled forested trails with a campground and forested trails without a campground as two distinct categories Of recreation sites. The construction of a campground on a forested trail currently without one is equivalent to the creation of a new site of the campground type coupled with the destruction of a site of the no campground type. Existing welfare rules for a simultaneous change in two prices (see Freeman [1979]) can be used to value the modification in this special case. If there are multiple characteristic differences between categories, however, partitioning can only value a change in all the characteristics. Because partitioning doesn't explicitly model the effect of individual characteristics on site value, it cannot distinguish the individual contribution of each attribute. Thus only in the special circumstance that modifications change a site from one distinct category to another is the partitioning approach appropriate for valuing site characteristics.

THE HEDONIC MODEL

The hedonic model treats goods as bundles of characteristics or attributes. The explicit market for heterogeous goods is assumed to be motivated by an implicit market for the underlying characteristics. Instead of prices of goods, one has prices of attributes. Instead of a demand and supply curve for goods, there is a demand and supply curve for attributes. Thus the tools of traditional economics are applied to an underlying dimension of consumer choice. However, unlike traditional markets where units of characteristics are traded individually, the purchase of characteristics occurs in discrete packages which cannot be unbundled. The market solution for characteristics consequently does not have to be a constant marginal price (see Rosen [1974]). In fact, the marginal price for an attribute can depend not only on the amount of that attribute purchased but upon the amount of other attributes purchased as well.

As clearly developed in Rosen [1974], the hedonic model consists of an assumed market equilibrium and a set of underlying supply and demand equations. Unlike traditional markets, several supply and demand equations operate simultaneously, one for each level of characteristic provided. Consumers and suppliers are assumed to optimize given the market equilibrium set of prices (price gradients). This optimization process can be characterized in terms of traditional Marshallian demand and supply curves. The complete hedonic model then includes a market price gradient P(Z), a set of demand functions for attributes G(P,W), and a set of supply functions for attributes H(P,Y):

(2) $$P = P(Z)$$

$$Z = G(P,W) \tag{3}$$

$$Z = H(P,Y) \tag{4}$$

where Y is a vector of supply shift variables such as input prices and technologies. Since the price gradient in the above model is nonlinear, the marginal price depends upon the level of the attribute purchased. Marginal prices are endogenous (only the price gradient is exogenous) requiring econometric adjustments for proper estimation of the structural equations (see Mendelsohn [1984b]).

Because the nonlinearity of the price gradient can be used to identify the underlying structural equations, there have been several attempts to identify hedonic structural equations from single market data (a single price gradient). Although this single market approach is technically feasible (see Mendelsohn [1985]), it is based on tenuous assumptions which are not testable with single market data. Thus, it is entirely plausible that single market analyses of hedonic structural equations are pure nonsense (unidentified).

The identification problem has especially plagued application of the hedonic method to property values. Because estimation of implicit prices requires extensive data from housing markets and because it is difficult to obtain comparable data across housing markets, multiple market (multiple gradient) housing studies have rarely been performed (see Palmquist [1982] for a notable exception). Except for a few questionable studies of demand functions for attributes, hedonic property studies have been limited to analyses of price gradients (see Freeman [1979] for a review of environmental applications of hedonic property studies). Because only the price gradient is estimated, these applications can only value small changes in the available characteristics. Further, because the studies are tied to private property values, they are applicable to public land management in only a few circumstances (for example, for the hunting value of wildlife, see Livengood [1983]).

An alternative application of hedonic analysis more pertinent to the valuation of outdoor recreation on public lands is hedonic travel cost (see Brown and Mendelsohn [1984]). Instead of analyzing the purchase of sites as with hedonic property studies, hedonic travel cost focuses on the purchase of access to sites. Access provides for a single trip the bundle of characteristics at that site. By exploring how far individuals are willing to travel amongst sites to get different bundles, one can estimate the implicit prices or cost of obtaining individual site characteristics. Thus, the first step in the hedonic travel cost method is to estimate the implicit prices of characteristics for each origin by regressing site attributes on travel cost:

$$P = P(Z). \tag{2}$$

Individuals from different origins face different price gradients because the configuration of available sites and travel distances change with geographical location. Provided there are sufficient differences in opportunities (geographical variation) and that people have not systematically chosen origins because of the corresponding prices (this problem has plagued the market segmentation approach to hedonic property studies-see King [1974] or Strazheim [1974]), the underlying demand curves for site attributes can be estimated across origins:

$$Z = G(P,W) . \tag{3}$$

The number of trips a consumer would want to take given the price gradient he faces could be modelled either in terms of the exogenous price gradient, the endogenous marginal prices and average characteristics, or the endogenous average site travel cost and the average characteristics:

$$Q = B(P(Z), W) = B(P_i , Z, W) = B(P, Z, W) \tag{5}$$

where econometric adjustments have to be made whenever endogenous variables (Pi, Z, or P) are used. The system of equations including the price gradient, the demand for number of trips, and the demand for attributes captures the tastes of the consumers.

The hedonic travel cost method has been applied to value steelhead populations in Washington (Brown and Mendelsohn [1984]), trail characteristics in the Olympic National Park (Mendelsohn and Roberts [1983], deer density in Pennsylvania (Mendelsohn [1984c]), and the effect of forestry on recreation in the Cascade Mountains (Englin and Mendelsohn [1985]).

One of the attractive qualities of this approach is its ease with modelling continuous and numerous characteristics. The hedonic approach is also attractive when the policy issue is a small change in the quality of a single site. As long as the change has no perceptible impact on the price gradient, the existing hedonic price is a clean measure of the value of the change. The hedonic model is also facile with policy changes which alter the system wide level of characteristics proportionately across all levels of a characteristic. That is, policy changes which alter the height but not the shape of the hedonic price gradient are easily measured with the demand curve for the characteristic.

The hedonic travel cost model becomes more burdensome when policy changes alter the shape of the price gradient. For example, suppose the relevant policy issue is to change several medium quality sites to high quality sites. Such a transformation could alter the shape of the price gradient dramatically. For example, suppose the price gradient is originally linear. The proposed policy change might easily alter the price gradient to some nonlinear shape. In order to evaluate the welfare effect of a nonlinear transformation of the budget curve, one would have to determine the shape of the new price gradient, compute the individual's optimal choice of sites and other goods given the new gradient, and then evaluate now much the consumer values his original position relative to his new position. Although these calculations are theoretically feasible, we have little experience in understanding how site specific changes will alter the price gradient. Thus, this process of nonlinear adjustment is clearly complex if not also problematic to practice.

INDEX MODEL

The index model is, in a sense, a hybrid between the partitioning and hedonic models. Like the partitioning models, the analysis explicitly models the choice amongst heterogeneous goods. However, like the hedonic model, that choice is considered to be an explicit function of the characteristics of the site. Consumers are assumed to generate cardinal rankings of available recreation sites on the basis of the objective characteristics of those sites.

The earliest application of the index approach to recreation analysis is the gravity models of geographers. In one of the simplest version of this model, trips are allocated across sites upon the basis of the square distance to each site and an attractiveness component of each site Ai (see Huff [1962]):

$$Q_i = Q * (1/P_i^2) * A_i / \sum_{j=1}^{n} [(1/P_j^2) * A_j] .$$

Note that the aggregate number of trips taken to the site is exogenous in the model above. Prices and attractiveness serve only to allocate the aggregate trips across sites. Further, the functional form is somewhat restrictive forcing the own and cross price elasticities to be 2. On the positive side, the original gravity model does explicitly recognize substitution amongst sites.

A later more sophisticated version of the gravity model includes both an allocation component as well as an aggregate trip component. That is, site quality and site proximity not only can affect which sites the consumer chooses but also how many total trips the consumer takes. For example, Ewing[1980] posits the following more general model:

$$Q_i = [W*f(\sum_{k=1}^{n} A_k*g(P_k))] * [A_i g(P_i) / \sum_{k=1}^{n} A_k g(P_k)] .$$

The first term in brackets determines the aggregate number of trips and the second term allocates the trips across sites. Further, the use of the function g(P) rather than simply the square distance generalizes the overall model to incorporate different price elasticities. The gravity model is essentially a demand equation model at this point. However, one restrictive component of this model remains. The cross price elasticities remain the sane across sites.

A second difficulty also arose in this literature. How can the quality index A be measured? At least in the early gravity studies, the attractiveness index became a subjective valuation of the researcher or simply a redundant measure of Qi/Q. Thus, the first uses of quality indices to rank sites was not satisfactory. The indices were not explicitly based upon the objective characteristic of the site or they did not reflect the revealed tastes of users.

Further, because the gravity model simply predicts participation, it alone is insufficient to estimate site values. Some practitioners of this approach consequently append a value per trip or day to the end of these models in order to determine value (see Sutherland [1982], for example). This ad hoc adjustment fails to recognize that the same choice process which generates value per trip also determines trip choice. Consequently, assumptions about functional form used for the valuation part must be carried through to the trip generation analysis or the two sections will be inconsistent. Thus, one cannot use a gravity model to allocate trips across sites and then turn around and use an entirely different model (such as an arbitrary travel cost model) to value the individual trips or days at the site.

Cesario and Knetsch [1976] are the first to recognize the inconsistency between using separate models for trip allocation and trip valuation. Cesario and Knetsch consequently adopt a model similar to the general gravity model above and demonstrate that it can be used directly to estimate value. By integrating underneath the implied demand for trips to a site with respect to travel cost, one can estimate the consumer surplus associated with any given site. Further, even multiple changes in sites can be valued using these models provided the demand equations satisfy integrability conditions.

Unfortunately, as with gravity models in general, attractiveness is an arbitrary valuation in the Cesario Knetsch model. In order to make the index approach work, a method to estimate the appropriate index is needed. Two approaches have since been developed. The first is generalized travel cost which builds upon the simple travel cost model. The second is discrete choice modelling which builds upon the general gravity model described above.

The generalized travel cost model attempts to explain the observed differences in the simple travel cost visitation functions for individual sites by the characteristics of those sites. For example, if the simple travel cost model of site A is observed to be vertically above site B, presumably site A has more quality than site B. Although the original developer (Freeman [1979]) of this generalization was aware that multiple site choices complicate this model, most applications of the model assume that only the characteristics of the visited site matter. The characteristics of the site are consequently assumed to alter the height and possibly the shape of the simple travel cost visitation function:

$$Q_i = F(P_i, Z_i) \quad .$$

Note that by explicitly omitting the attributes of other sites, the methodology assumes that a site has a fixed value regardless of available substitutes. This assumption is clearly justified if one assumes there is only one site available (see Feenburg and Hills [1980]). In practice, however, the approach has been applied to examples where there are clearly multiple opportunities facing each recreation participant (see Vaughn and Russell [1983] or Desvousges, Smith, and McGivney [1983]). Implicitly, these applications either assume that (1) the cross price elasticity between the measured site and all other sites is zero or (2) the proximity of all other sites is the same for participants from every ring visiting the measured site. Since neither of these conditions are likely to hold, the generalized travel cost model is subject to at least error. There is also a very real possibility that the model will tend to bias certain coefficients. In particular, whenever a group of sites tends to be similar (for example, because of a common natural feature such as tall mountains) the attribute held in common is likely to be undervalued (because the close substitution amongst sites here is being ignored). In contrast, whenever a site is unusual in reference to nearby sites, the generalized travel cost model will tend to overvalue the unusual feature (the absence of substitutes is being ignored).

The second approach to measuring quality indices is the discrete choice model. The discrete choice model has its origins in the gravity model although it offers a much improved opportunity to measure the quality index. A second advantage of the discrete choice method is its explicit development from utility theory. This strong utility base has permitted both Morey [1984] and Hanemann [1984] to develop sound welfare comparisons from this methodology.

The underlying utility model used to justify discrete choice models assumes each participant possesses an index of attributes b(Z) which he can apply to rank sites. In its simplest form, the model assumes that the individual visits and thus values only the best available site. Consequently, if all consumers were alike there would be no substitution amongst sites, everyone would simply go to the best site all the time. Rather than incorporating substitution into the deterministic component of the model as with both the partitioning and hedonic models, the discrete choice models depend upon a random utility component to replicate observed substitution. Thus although one site might have a slightly higher ranking than another, the individual may nonetheless visit the inferior site some of the time depending upon his random behaviour. More formally, the model posits a probability that each site will be chosen:

$$(9) \qquad \pi_i = Pr\{ U[b(Z_i),Y-P_i;e_i] > U[b(Z_k),Y-P_k;e_k] \} \quad .$$

The choice depends upon the two deterministic components of the utility function, b(Z) and all other goods, as well as the random error terms e. Thus the distribution of visits across sites depends upon the cardinal ranking from the index and the variances and possible covariances amongst the error terms. The greater the difference in quality between any two sites, the more visits to the better site. The greater the variance, the fewer visits to the higher quality site.

Estimation of the discrete choice models builds upon the basic econometric multinomial logit work of Luce [1959] and McFadden [1973,1981]. If the error terms are assumed to be independently and identically distributed extreme value variables, then (9) reduces to:

$$(10) \qquad \pi_i = e^{BZ_i} / \sum_{k=1}^{n} e^{BZ_k} \quad ,$$

which is just the gravity model in its more general form. This model can be estimated easily with maximum likelihood techniques. Morey [1981,1984], Hahnemann [1984,1985], and Peterson,Dwyer, and Darragh [1984] are the first to apply the technique to recreation analysis.

There are three remaining problems with the discrete choice model in increasing importance. (1) The total number of trips or budget on trips is exogenous. (2) The choice of functional. form for the utility function is problematic. (3) The substitution amongst sites is restrictive.

Like the eatly forms of the gravity model, the early applications of discrete choice treat the total number of trips as exogenous. To correct for this shortcoming, a trip generation component needs to be added to the model. This could be done explicitly as part of the logit formulation, as suggested by Peterson,Dwyer, and Darragh [1984]:

$$(11) \qquad Q_i = [\sum_{k=1}^{n} e^{BZ_k}]^{a1} * [P_i^{a2} * e^{BZ_i} / \sum_{k=1}^{n} e^{BZ_k}] \quad .$$

The term in the first bracket is the trip generation component and the term in the second bracket is the trip allocation component. The above equation can then be estimated with standard multinomial logit packages. The alternative is to add a second trip generation demand function for a two equation model. For example, one could posit a combination of (10) and the following:

$$(12) \qquad Q = F(P,BZ,W)$$

where P and BZ could reflect the average observed site or possibly the distribution of observed sites. Since these variables are endogenous to the two equation model as is Q in (10), an instrumental variables approach could be used to estimate both equations.

With all empirical estimation techniques, the question of appropriate functional form is pressing. With the partitioning and hedonic models, several forms must be tried to test which fits the data most closely. However, with the discrete choice models, functional form issues are even more urgent. Because it is the utility function which requires the functional form, casual choices of form result in hidden assumptions about behavior. Hanemann [1984], for example, demonstrates just how restrictive simple assumptions like linearity tend to be when imposed on the utility function. Like functional form choice for demand functions, several functional forms for the utility function must be tried. Unfortunately, flexible functional forms such as the translog demand function do not have equivalently flexible utility counterparts as yet. Consequently, the importance of testing the implicit assumptions of functional form are even more critical with the discrete choice model than with other empirical techniques.

The third and perhaps most serious drawback of discrete choice models is the restrictive assumptions about substitution required to facilitate estimation. One of the properties of the Luce [1959] model is the assumption of the axiom of independence of irrelevant alternatives. Differentiating (10) with respect to In z(jk) , yields:

$$(13) \quad \partial \ln \Pi(i|Z_B, B) \;/\; \partial \ln z(jk) = B_k\, z(jk)\, \Pi(j|Z_B, B) \quad .$$

The cross elasticities for each characteristic z(jk) are the same across all sites and do not depend on the characteristics of the site(i). For example, if one adds a toilet to some already developed site j, that toilet would have the same impact on the choice of all other sites whether or not site i was a developed campground like j or a remote undeveloped wilderness. Another quality of this property is that the ranking between any two sites is not affected by any of the other alternatives. The restrictiveness of this assumption has been popularly illustrated with a modal choice example between a car and a red bus. The introduction of a blue bus, one would expect should affect the red bus more than the car because it is a perfect substitute for one but not the other. The model, however, assumes that it affects use of both existing modes equally.

In order to move away from the axiom of irrelevance of independent alternatives, Hausman and Wise [1978] have proposed a multinomial probit alternative. Except for a slight distinction in the tails of the distributions, the cumulative normal and logit distributions are quite similar. Hausman and Wise demonstrate that the probit model with zero off-diagonal covariance terms is equivalent to the logit model. They consequently add nonzero off-diagonal elements to the error covariance matrix in order to capture substitution across sites. Unfortunately, this approach requires one to integrate across all available choices (sites) in order to estimate. The complexity of this calculation reduces the number of alternatives possible. Hausman and Wise, themselves, only use three alternatives and they suggest that current algorithms can handle no more than five sites. Of course, five sites is totally inadequate for developing an index of quality. With only five different combinations of characteristics, there is no reliable way any technique could sort out the individual contribution of two or more characteristics to quality.

A second approach to relax the substitution assumptions of teh logit model has been suggested by McFadden [1981]. He suggests using the logit model to estimate a decision tree. With a decison tree, the multiple site choice problem can be divided down to a series of more limited choices. For example, to be completely free of the independence axiom, one could focus on binomial decisions entirely. For example, the consumer would first choose which of two classes of sites to visit, then which of two major subclasses within the chosen class, and...finally which of the remaining two sites to visit. Of course, estimation of this sequential model could follow exactly the reverse process starting with multiple pairs of sites and ending with a single pair decision.

The basic problem with the decision tree framework is that it is arbitrary. Instead of a single restrictive but simultaneous comparison across all sites, the decision tree framework provides a highly structured series of pairwise comparisons. Although this serial analysis is more flexible in that substitution across sites can vary, the specific order of comparisons dictates the final substitution observed. In McFadden [1981], the coefficients depended upon the decision tree chosen. Since theory does not dictate which tree is to be preferred, the results of any single tree are arbitrary. It is clearly important to explore under what conditions a single tree could be chosen. It would also be helpful to know when all the trees will provide consistent responses. Unfortunately, it is likely that the limiting condition is precisely the order independence which the technique is designed to avoid.

CONCLUSION

This paper is intended to be a critical appraisal of the state-of-the-art of recreation modelling. Focusing upon the relative merits of each revealed preference approach, the limitations of restrictive assumptions underlying each method have been emphasized. It is important, however, not to lose sight of the tremendous progress in this area and of the high quality of current research. Today, the applied researcher has many options to estimate the value of sites and their characteristics. Each of these methodologies are soundly based in economic theory and econometric practice. Resource valuation is one of the most exciting and powerful components of natural resource economics.

Of course, new ideas and new applications generate as many new quaestions as they answer. Each methodology would clearly benefit form specific additional research. The aprtitioning approach, for example, could use some formal work on optimal grouping or clustering strategies. The appropriate choice of decision trees in discrete choice models deserves attention. The bias and lack of precision from the absence of site substitution in the generalized travel cost model needs to be studied. The effect of site changes on the hedonic travel cost price gradient needs to be known.

We, as a profession, are on the edge of measuring the value of a host of natural resources which have historically escaped measurement. With adequate support, these new methodological capabilities can be turned into a vast array of promising new management and policy techniques.

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A MODEL TO ESTIMATE THE ECONOMIC IMPACTS ON RECREATIONAL FISHING IN THE ADIRONDACKS FROM CURRENT LEVELS OF ACIDIFICATION

-- DRAFT --

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AERET

1.0 INTRODUCTION

The analysis contained in this paper is part of a project whose goal is to estimate the economic damages to recreational fishing from current levels of acidification. The Adirondack Mountain region was selected as the focus for this study since it is the region where current levels of acidification are believed to be having the greatest deleterious effect on fish populations. Acid deposition is commonly viewed as a regional problem since large portions of Pennsylvania, New York, New England and Eastern Canada have high levels of deposition. However, from the perspective of damages to fish populations, the fresh water effects of current levels of acid deposition are expected to occur in narrower geographic areas. Two factors must interact before fish populations will experience adverse effects -- one, the watersheds must be exposed to high levels of acid deposition; and two, the watersheds must be sensitive, i.e., have a low buffering capacity. Even though broad regions are exposed to high levels of acid deposition, the sensitive lakes and streams tend to be grouped into smaller areas. Our current efforts are focused on examining the benefits of reductions in acidification in New York. The regions containing sensitive lakes in New York are essentially limited to the Adirondack and Catskills mountain regions, and the Hudson Highlands.

A traditional approach for estimating the economic value of recreational sites has been to use the travel and on-site costs incurred by visitors as a proxy measure of the price paid to use that site. Early travel costs studies focused on changes in the supply of sites, i.e., the addition of a new site or the loss of an existing site. The estimation problem faced by this project is different. Acidification will not change the number of sites available for fishing, but will change the characteristics of those sites. The reason for this is that it is not tractable to view each lake as a separate site. There are thousands of lakes in the Adirondack Ecological Zone, which makes a lake by lake analysis impossible. Instead, each site must be viewed as a geographic area containing a number of lakes. Each site can then be characterized by the number of lakes it contains that have certain characteristics. Possible site characteristics include the number of acres of cold water, two story, or warm water lakes. In this framework, acidification could, for example, result in a change in the number of acres of cold water lakes that are able to support fish populations. The estimation problem is to determine how a change in these site characteristics will affect the value of that site as a recreational fishery.

Two data sets were identified that contain data useful for an analysis of Adirondack lakes -- the New York Anglers Survey and the Adirondack Ponded Waters Survey. The New York Anglers Survey contains data on fishing activity throughout the state; however, the Adirondack Ponded Waters Survey only contains data on lakes and streams in the Adirondack Ecological Zone. As a result, the geographic scope of the study was necessarily limited to this area. This may not pose a significant problem for a national assessment of damages, since documented damages to recreational fisheries at current levels of deposition have largely been limited to the Adirondack Mountain regions. Lakes and streams in New England, Minnesota, Wisconsin and selected areas in other regions of the U.S. are sensitive to acid deposition and may be affected in the future. Nevertheless, at the current level of acidification most deleterious effects on recreational fisheries are felt to be occurring in the Adirondack Mountains.

The recent environmental benefits estimation literature contains several approaches for incorporating site characterisitics within a travel-cost framework. Prominent applications incorporating site characteristics into a travel cost model are Vaughan and Russell (1982); Desvousges, Smith and McGivney (1983); Morey (1981); Greig (1983); Brown and Mendelsohn (1984); and Bockstael, Hanemann and Strand (1984). This literature includes several diverse approaches each with certain strengths and weaknesses. The use of site characteristics in travel cost models is a recent development. As a result, new applications and techniques are currently being researched.

The problem of incorporating site characteristics within a travel cost model can be illustrated using a conventional Burt and Brewer (1971) type travel cost model. This "conventional" travel cost model estimates a separate demand equation for each fishing site. These demand functions for "n" fishing sites are shown below.

$$\begin{aligned} &\text{Site 1 equation: } V_{1q} = B_{10} + B_{11} P_{11} + B_{12} P_{12} + \ldots + B_{1q} P_{1q} + C_{1j} S_{qj} + U \\ &\quad\vdots \\ &\text{Site n equation: } V_{nq} = B_{no} + B_{n1} P_{n1} + B_{n2} P_{n2} + \ldots + B_{nq} P_{nq} + C_{nj} S_{qj} + U \end{aligned} \qquad \text{(eq. 1)}$$

where:

V_{iq} = the visitation rate to site i from origin q, usually measured in visitors per 10,000 people

P_{iq} = the price of visiting i from origin q in terms of travel and time costs.

B_{iq} = the regression coefficients on the price variables

S_{qj} = socioeconomic variables for origin q

C_{nj} = regression coefficients on socioeconomic variables

U = random term

For example, the data that would be used to estimate the site 1 equation is simply the visitation rate, and the travel costs from each of the q origins to each site. The underlying assumption is that the visitation rates to site 1 will be lower for origins more distant from site 1; that is, as the costs of traveling to site 1 increase the visitation rate will decline.

In this conventional travel cost model, it is not possible to examine how the characteristics of the site affects the visitor's demand function. The equation for each site is estimated separately. As a result, there can be no variability in the site characteristics of just one site. Several different approaches for incorporating site characteristics within a travel cost framework have appeared in the recent literature. These new methods can be classified into several basic approaches:[1]

1) The varying coefficient travel cost model as characterized by Vaughn and Russell (1982), and Desvouges, Smith and McGivney (1983);

2) The explicit utility function approach as characterized by Morey (1981) and Grieg (1983);

3) The hedonic travel cost model as developed by Brown and Mendelsohn (1984).

A variant of the varying coefficient travel cost model was selected for this application. The varying coefficient travel cost model approach selected for use in this project is similar to that used by Vaughn and Russell (1982), and Desvouges, Smith and McGivney (1983). This approach utilizes a two step framework. The first step consists of estimating a separate visitation-travel cost equation for each site. The second step uses the

[1] W.M. Hanemann in Chapter 9 of Bockstael et al. (1984) presents a random utility model based travel cost formulation which also incorporates site characteristics.

regression coefficients from the step one equations as dependent variables and regresses these coefficients on the site characteristics. To use a simple example, the conventional Burt and Brewer visitation demand function for site "i" is:

$$V_{iq} = B_{io} + B_{i1} P_{i2} + \dots + B_{iq} P_{iq} \qquad \text{(eq. 2)}$$

where V_{iq} is the visitation rate from origin q to site i and P_{iq} is the travel cost from origin q to site i. Since a separate equation is estimated for each site, there are "i" different estimates of each coefficient. These regression coefficients represent the relationship between travel costs and visits. The variability in the magnitue of the regression coefficients in the different site equations are likely to be due to the relative desirability of the site in terms of the site's characteristics. This can be tested in the second step regressions where the regression coefficients are regressed against the characteristics of each site:

$$\begin{aligned} B_{i0} &= A_{00} + A_{01} Z_{1i} + \dots + A_{0k} Z_{ki} \\ B_{i1} &= A_{10} + A_{11} Z_{1i} + \dots + A_{1k} Z_{ki} \\ &\vdots \\ B_{iq} &= A_{q0} + A_{q1} Z_{1i} + \dots + A_{qk} Z_{ki} \end{aligned} \qquad \text{(eq. 3)}$$

where Z_{ki} is the level of the k^{th} characteristic at site i and the A_{ik} are new regression coefficients on the site characteristic variables. This two step procedure can be combined into an equivalent one step method by substituting equation 3 into equation 2 to yield:

$$\begin{aligned} V_{iq} = {} & (A_{00} + A_{01} Z_{1i} + \dots + A_{0k} Z_{ki}) + (A_{10} + A_{11} Z_{1i} + \dots + A_{1k} Z_{ki}) P_{i1} + \dots \\ & + (A_{q0} + A_{q1} Z_{1i} + \dots + A_{qk} Z_{ki}) P_{iq}. \end{aligned} \qquad \text{(eq. 4)}$$

Equation 4 includes both site characteristics and travel costs as interaction terms. This equation can be estimated using pooled data across sites.

Generalized least squares (GLS) procedures should be used to estimate equation 3 or equation 4. This two stage procedure will introduce heteroskedasticity into the error term of the second stage regressions. The second stage regression using only one site characteristic as the dependent variable is:

$$B_{i0} = A_{00} + A_{01} Z_1. \quad \text{(eq. 5)}$$

The dependent variable B_{i0} is an estimated regression coefficient from the first stage regression; therefore, the error term for the regression shown as equation (5) is influenced by the error in the estimated coefficient. This introduces heteroskedasticity in the regression equation error term. Simply stated, if the estimated variance of B_{i0} from the stage 1 regression in large (i.e., B_{i0} is estimated imprecisely) this will influence the error term in the regression shown in equation (5). This can be corrected by using GLS procedures where the estimated standard errors for the regression coefficient from each site are used as the correcting weights.

The two applications of varying coefficient travel cost model cited previously -- Vaughan and Russell (1982), and Desvousges, et al. (1983) - found site characteristics to be significant in the second stage regression equations. The available data and nature of the estimation problem makes this application of this technique to the Adirondacks somewhat different from these previous applications of the varying coefficient approach. For example, Vaughan and Russell (1982) used a sample of fee fishing sites in the Northeastern United States. These sites were typically widely dispersed geographically making it unlikely that visitors to one site would have also visited another of the sites included in the data set and, even if they did, there was no way to learn this from the data. The Desvousges et al. (1983) visitation data was from 46 U.S. Army Corps of Engineering recreation sites. Again, these sites were scattered throughout the United States. These applications can be contrasted to the Adirondacks region being examined in this project where all of the sites are located in a small region and are, in fact, adjoining. This results in a visitation data set where many fisherman have visited more than one site.

The specifics of the data available for this project made it desirable to use a variant of this two stage approach. Instead of using ordinary least squares techniques to estimate the coefficients of the first stage site demand equations, a Tobit procedure is used. The Tobit estimation procedure is able to take full advantage of the available data on individual fishermen. First used in Tobin (1958), the Tobit procedure estimates both the probability of an individual visiting a given site as well as the number of days the individual will spend at that site, given that a visit is made. Taken together, these two estimates can be used to calculate the expected value of days spent at each site for each individual.

The procedure used to incorporate site characteristics within this travel cost model is very similar to the varying coefficient travel cost model as depicted by equations 2 and 3. The only difference is that the first stage regression coefficients of equation 2 are estimated using a Tobit procedure. In the second stage, these regression coefficients are used as the dependent variable and regressed against the site characteristics using a generalized least squares procedure to correct for heteroskedasticity.

2.0 DATA

There were two main data sources for this project. These were the 1976-1977 New York Angler Survey and the Adirondack Lake and Pond Survey (Ponded Waters Survey). Both data sets were compiled by the New York State Department of Environmental Conservation (NY DEC).

2.1 THE NEW YORK ANGLER SURVEY, 1976-1977

The New York Angler Survey for 1976-1977 is the most recent data source from which information on fishing activity and travel costs can be compiled for the Adirondacks. The Angler Survey consisted of a questionnaire mailed to a three percent sample of fishermen licensed in New York State between October 1, 1975 and September 30, 1976. The questionnaire elicited responses about fishing activity in New York State between April 1, 1976 and March 31, 1977. Of the 25,564 questionnaires mailed, 11,721 responses were received.

The questionnaire consisted of three major sections: one - fishing activities, expenditures, and preferences; two - attitudes and opinions; and three - participant background. The first section of the Anglers Survey examined fishing activities, expenditures and preferences. This section collected data on where, for how long, for what species, and by what methods the respondent fished. Data on expenditures per fishing location for that year and for total equipment expenditures were also requested. Questions relating to preferred species, reasons for fishing and what makes a fishing trip successful were included in this section. The attitudes and opinions section of the Anglers Survey was mainly concerned with New York's fisheries management programs, procedures and regulations.

The participant background section elicited information on fishing background, whether or not the respondent belonged to a fish and game club, other recreational activities, and household income. A summary of the Angler Survey appears in Kretser and Klatt (1981).

Since the 1976-77 Angler Survey gathered information on fishing throughout New York State, it was necessary to select only observations on fishing trips to the Adirondacks region. Fishing locations in the Angler Survey are identified by name of water and county. Relevant observations for this project were chosen by selecting only those fishing locations in counties in which the Adirondacks lie. The counties included are: Clinton, Essex, Franklin, Fulton, Hamilton, Herkimer, Lewis, Saint Lawrence, Saratoga and Warren. This resulted in data on 3015 individual anglers who visited 6053 fishing locations. Thus the average angler who fished in the Adirondacks fished at two different locations within the Adirondacks.

The 6053 visits by individuals were to 760 different fishing sites, 504 of which were lakes and ponds, the remainder being rivers and streams. Since adequate site characteristic data was available only for lakes and ponds, the effective sample size was further reduced to data on visits to the 504 lake and pond locations.

Data on expenditures in transit to the site and at the site were requested by the Angler's Survey although not all individuals reported these expenditures. Travel expenditure data was available for 62.3 percent of the 6053 sites, and on-site expenditure data for 57.3 percent of these sites. Expenditures on equipment were also requested, but improperly coded and entered onto the tape, therby making this data unuseable.

The Angler's Survey contained no data on distances traveled to each site or time spent traveling to the site. Distance data was estimated manually using the Zip Codes included in the Angler Survey. Given the large number of observations, this was a time consuming task. Travel time was approximated by assuming an average driving speed and dividing distance by this speed.

Socioeconomic and other respondent background data contained information on household income, date of birth, years of education, and years of fishing. Other questions in this section concerned whether the individual had a preferred species to fish for, whether or not the respondent was a member of a fish and game or other sportsmen's club, and their participation in other recreational activities. A number of attitudinal questions were also included which examined the individual's reasons for fishing, factors important to a successful fishing trip, and limiting factors for respondents who do not fish as often as they would like.

2.2 ADIRONDACK LAKE AND POND SURVEY

Site characteristic data was obtained from the Adirondack Lake and Pond Survey[1] (ponded Waters Survey). This data base includes information on 3506 ponded waters in the Adirondacks area. The Ponded Waters Survey is not entirely comprehensive; not every ponded water in the Adirondack area has a complete record. For example, there are only 2409 pH records in the most recent chemistry survey data for those waters which have been surveyed. Also, not all lakes and ponds are surveyed each year. The most recent survey for a particular water may have been last year, or it may have been 20 or more years ago. Only 1217 of the 2409 pH records date from 1960 to the present. The New York State Department of Environmental Conservation (NY DEC) is continuing to update this data base.

The data in the Adirondack Lake and Pond Survey refers to ponded waters only. Stream fishing is also important in the Adirondacks. There are approximately 5,000 miles of coldwater fishing streams in the Adirondacks, with about 3500 miles of these open to public fishing (Pfeiffer, 1979). Over 700 miles of warmwater fishing streams also exist, with approximately 480 miles open to public fishing (Pfeiffer, 1979). Unfortunately, stream characteristic data are not as readily available as ponded water data in the Adirondacks. Miles of streams open to public fishing appears to be available on a county basis, but may be difficult to obtain on a more disaggregated basis.

Of the general site characteristics, surface area and elevation were the best available, existing for at least 80 percent of the waters. Shoreline length would be a useful alternative to surface area and is listed as a variable in the documentation, but it did not exist for any waters. Another potentially useful characteristic listed in the documentation but for which no data exist is the distance to nearest public road or trail. This accessibility measure could have been quite useful. The public or private ownership

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[1] This survey is continually updated. The survey used in this analysis was the version available in February, 1984.

classifications can be useful if it is desired to limit the number of ponds, or surface area in a site to only those open to public use.

The current management class of a water can be useful for determining the different types of fishing opportunities available within a site, and their relative importance. Management classifications in the survey included warm water, two story, cold water and brook trout fishery classifications. Although only 38 percent of the waters were categorized by management class, these waters comprise 87.7 percent of the total measured surface area. Thus this variable may be used with a reasonable level of confidence.

Two issues surround the relevance of the pH and alkalinity data which are available. One is the fact that much of the data, perhaps a large portion, may be extremely old and thus no longer accurate. Secondly, pH data existed for only 35 percent of measured surface area and alkalinity for only 52 percent. As a result, estimates of the effect of acidification on fishable acreage of ponds made by others were used in this analysis. Other research in the National Acid Precipitation Assessment Program has calculated the change in fishable acres due to acidification.[2]

Since 7½ minute quads were chosen as the components of the sites, the data extracted from the original Ponded Waters tape for each individual water needed to be aggregated by quads. In the current formulation, site characteristics are defined in terms of surface area. For a given quad containing a number of lakes and ponds, one characteristic is the total surface area of these ponds. Surface area is also broken down by various discrete categories of other relevant characteristics. For elevation, there is surface area below 1500 feet, between 1500 feet and 2000 feet, and above 2000 feet. Surface area is also broken down by the various fishery management classes and ownership categories.

2.3 INTEGRATION OF THE ANGLERS SURVEY AND THE PONDED WATERS SURVEY

The Angler Survey and Ponded Water Survey used different methods for identifying particular bodies of water and a mapping from one code to the other was necessary. Indi-

[2] In this report, NAPAP funded work by Dr. Joan Baker at North Carolina State University was used to obtain estimates of how acidification will affect the acreage of water available for fishing.

vidual waters in the Ponded Waters Survey are identified by a watershed and pond number combination. For the Angler Survey, a water name and county was supplied by respondents. A code was created by the NY DEC for identifying waters in the Angler Survey which consisted of locating the water in the report, Characteristics of New York Lakes, Part 1 -- Gazatteer of Lakes, Ponds and Reservoirs (Greeson and Robison, 1970). This was done by coding each water by a number where the first two digits indicated the page and the second two digits the line of the Gazatteer listing the water name and location. The result was a time consuming process where each lake or pond in the Anglers Survey had to be be looked up by hand in the Gazatteer and matched to a lake with hopefully the same name and location in the Ponded Waters Survey. NY DEC personnel cautioned against a one-to-one mapping of waters due to concerns with the Angler Survey. A particular concern was that anglers may not always know exactly where they fished. They may believe they are at one lake or pond when they are actually at a different lake nearby. Or they may use a name for the lake which is different from the official name for that lake. Also, there can be several lakes within a county with the same name. In these cases NY DEC personnel had to use their judgement, based on knowledge of popular fishing areas and species availability in these waters, in coding fishing locations. Since both the Gazatteer and the Ponded Waters Survey include identification of the 7½ minute USGS quadrangle in which a water's outlet lies, the fishing locations from one survey to the other were mapped on the basis of 7½ minute quads. As a result, even if the fisherman gave the name of a nearby lake in error, his visit will still be mapped to the correct site as long as both lakes are in the same 7½ minute quadrangle. A more detailed discussion of site selection will be given below.

2.4 SITE SELECTION

Defining sites to be used in the travel cost model raised several issues. One of these issues has already been discussed, namely the problem of not being able to cross-reference waters between the Angler and Ponded Waters Surveys on a one-to-one basis. The use of 7½ minute quads should serve to mitigate this issue. However, the use of 7½ minute quads poses other problems. Most importantly, the 7½ minute quad associated with any lake or pond refers to the quad in which that water's outlet lies. For large bodies of water, this quad could be several miles from where an angler actually fished. In other cases, a group of lakes may cross several quad boundaries yet still exist in relatively close proximity with easy access from one to the other, making this group of lakes a reasonable candidate for a site (destination). There are few major roads within the Adirondacks, thus accessibility was another site determinant.

The issues mentioned above were considered when aggregating the individual 7½ minute quadrangles into larger sites. The sites were constructed by grouping together as geographically homogeneous 7½ quads as was possible. If the outlet of a lake was in one 7½ minute quad while the body of the lake was in a neighboring quad, both quads were included in the same site. Sites were also constructed to include groups of similar lakes such as the Saranac Lakes. Another consideration was the highway system where quads having a common access were included in the same site. From an empirical viewpoint, there have to be enough sites for sufficient degrees of freedom in the second step regression. A site specification resulting in 24 sites was ultimately decided upon.

3.0 THE MODEL

This chapter is divided into three sections. Section 3.1 presents a simple participation model. A participation model relates recreational activity to the supply and quality of recreation opportunities available at different sites. Compared to travel cost models, participation models have less stringent data requirements and assumptions. Participation models do not use data on travel costs and, therefore, the assumptions required for travel costs to serve as the basis for calculating consumer surplus based values for the recreation activity do not have to be imposed. However, participation models do not have the ability to infer values for the resource from the empirical analysis, but the model can show how participation is expected to change as recreation opportunities increase due to improved water quality. If the value of additional recreation days can be inferred from other sources, then an estimate of the value of the improved water quality can be obtained by multiplying the increase in recreation days times the value per day.

An empirical model designed to estimate the value of the resource for recreational fishing is presented in Sections 3.2 and 3.3. Section 3.2 takes advantage of the data available on expenditures to obtain an estimate of the average per mile travel cost incurred to produce one fishing day. The ability to estimate this dollars per mile per fishing day travel cost is important for the analysis since the visitation data from the Anglers Survey is expressed in terms of fishing days spent at a site and the survey did not contain information on whether these days were all taken during one trip, two trips or many trips. Section 3.3 presents the estimation of the relationship between travel costs and fishing days at each site. Section 3.4 incorporates the characteristics of the site into the travel cost framework.

3.1 PARTICIPATION MODEL ESTIMATION

The first step analysis of the visitation data consisted of the estimation of a simple participation model. As was discussed above, participation models have less stringent data requirements and assumptions than do travel cost models but they entail the loss of the ability to infer values from the estimated model.[1] This model relates the number of fishing days at each of the 24 sites against selected characteristics of the site. The site characteristics that were used include measures of fishable acres of lakes and ponds, and the total catch rate defined as the average number of fish caught per fishing day at each site. Once this model is estimated, it is possible to calculate an estimate of the change in fishing days due to a change in the site characteristics. In this participation model, travel costs and distances traveled were not considered, but they are incorporated into the next phase of the analysis procedure.

The results of the participation model runs are shown in Table 3-1. The coefficients on the fishable acreage variables are significant in all runs and the magnitudes of the coefficients were consistent across the different specifications. The coefficients on the acreage variables ranged in magnitude from .061 to .0978, with the majority of the coefficients clustered between .0845 to .0978. The one exception was the coefficient on the acres of cold water in equation 2 which had a negative sign, but was not significant. These data show a relationship between the total number of fishing days spent at a site and fishing opportunities as measured in fishable acreage.

The total catch rate variable did not perform as well as the acreage variables. The catch rate variable was significant in two of the specifications, but the magnitude of the coefficients varied considerably -- from 49.8 to 199.4. The lack of stability of the coefficients on the catch rate variable would tend to make predictions based on this variable less reliable.

The reasonableness of the magnitudes of the coefficients on the acreage variables can be examined by performing some calculations using equation 1 from Table 3-1. The mean values across all 24 sites for the variables total days, acres of warm water, and acres of two story ponds are 1145.8 days, 4516 acres warm water, and 3645 acres of two-story ponds. Using these values as depicting an "average site," the effect on total fishing days of a 10 percent reduction in fishable acreage can be calculated:

$$\text{days} = .0958 \times (451.6) + .0845(364.5)$$

$$= 74.06 \text{ days}$$

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[1] This is discussed in more detail in Freeman (1979), Chapter 8.

Table 3-1

Participation Models With Total Fishing Days at a Site as the Dependent Variable

(t-values are in parentheses)

Regression Number	Total Park Acres	Net Park Acres	Warm Water Acres	Two Story Acres	Cold Acres	Acres at less than 1,500 feet in Elevation	Total Catch Rate	R^2	Overall F
1.	--	--	.0958	.0845	--	--	42.04	.60	9.49
			(4.44)	(3.80)			(.418)		
2.	--	--	.0972	.0851	-.540	--	49.84	.635	7.849
			(4.59)	(3.90)	(-1.33)		(5.04)		
3.	--	.0978	--		--	--	199.4	.615	16.03
		(5.66)					(1.97)		
4.	--	--	--	--	--	.076	-85.1	.55	8.23
						(4.16)	(.84)		
5.	.061	--	--	--	--	--	7.44	.32	5.01
	(3.16)						(.62)		

The net result of a 10 percent reduction in fishable acreage at the "average" site is a reduction of 74 fishing days, or a 6.5 percent reduction in fishing days at the site.

One problem that possibly limits the usefulness of these participation models is the lack of significance of the cold water acreage variable. Acid deposition is expected to largely affect cold water lakes and ponds and to have a much smaller effect on warm water and two-story lakes and ponds. To further examine this particular issue, a second set of participation models were estimated. Rather than using total fishing days as the dependent variable in this model, a new variable defined as brook trout fishing days was used. This variable was constructed by taking all the days at each site where the individual reported to have caught at least one brook trout. Other species of fish may have been fished for and caught as well, but if brook trout were caught, then these days were classified as brook trout days.

The result of the participation models using brook trout days at each site as the dependent variable are shown in Table 3-2. In contrast to the participation models using total fishing days, the cold water acres variable in this model had the appropriate sign and a t-value of 1.38. Although the t-value is low, it is significant at the 80 percent confidence level with a two-tailed test and significant at the 90 percent level with a one-tailed test. The catch rate variable was significant and was stable in magnitude across the specifications examined. These models indicate that a reduction in the brook trout catch rate from four fish per day to three fish per day would reduce the number of fishing days at that site by approximately 37 days. Also, the coefficient on the cold water acres variable was similar in magnitude to the coefficients on the warm water and two-story acreage variables in the total fishing day participation models.

3.2 ESTIMATION OF PER MILE TRAVEL COSTS

The data contained in the New York Anglers' Survey presents certain problems for its use in a travel cost valuation model, but it also has certain advantages relative to the type of data commonly used in travel cost models. One problem with the Anglers' Survey data is that it contains information on the number of days spent at a site rather than the number of trips made to a site. This is the reverse of the problem typically faced by travel cost

Table 3-2

Participation Models Using Brook Fishing Days as the Dependent Variable

(t-values in parentheses)

Regression No.	Cold Water Acres	Two Story Acres	Brook Trout Acres	Acres at Greater than 2000 ft in Elevation	Brook Trout Catch Rate	R^2	Overall F
1.	.088 (1.38)	.0086 (2.67)	- -	- -	37.81 (2.22)	.445	5.08
2.	- -	- -	.0224 (1.32)	- -	32.55 (1.67)	.239	3.15
3.	- -	- -	.004 (.224)	.005 (.225)	37.98 (2.88)	.309	3.13

models where there is data on the number of visits, but generally there is no information on the duration of the stay. A positive aspect of the Anglers' Survey is that it contains travel expenditures as reported by the individual. This expenditure data can be used to obtain estimates of the per mile travel costs. These estimates may be preferred to estimates from external sources such as the often used American Automobile Association's (AAA) estimates of average travel costs since they may better represent the individual's perceived travel costs (i.e., the costs on which individuals base their fishing location decisions). Another advantage of this particular data set is that it contains information on individuals who visited each site as well as those who chose not to visit the site. The decision by an individual to not visit a site provides useful information that can be incorporated into the estimation of the visitation equation.

Since the New York Anglers' Survey only contains data on the number of days spent at a site, having a fisherman indicate that he spent eight days at a site does not provide any information on whether this was one eight-day trip, two four-day trips or four two-day trips. Depending on the number of trips taken to provide the eight fishing days at the site, the travel costs associated with the production of those eight fishing days could be very different. For example, assume the site is 100 miles away and travel costs are ten cents per mile, then one round trip would cost $20.00. If the eight days at the site represented one trip, then the total travel costs to produce those eight fishing days would be $20.00, or $2.50 per day. If the eight fishing days were the result of four two-day trips, then the total travel cost would be $80.00, or $10.00 per fishing day.

This problem results in potentially large measurement errors in the estimated travel costs. It could be solved if there were data on the number of trips and length of trips. With such data, separate models could be estimated for trips of different lengths. The problem faced by this analysis is not dissimilar from other travel cost applications that have used data sets containing information on the trips to a site, but no information on the number of days at a site. One commonly used procedure to get around this problem is to use only trips of short distances that most likely represent only one-day outings and then assume that all days spent at the site are one-day trips. This is a possible option but is not desirable for this application since the purpose of the model is to obtain an estimate of the total value of the resource. Using a subset of data that represents only one-day trips could result in biased estimates.

Given the New York Anglers' Survey data set, the best option for the dependent variable in the travel cost model was the number of days at the site. For this dependent variable to be most meaningful in a travel cost model framework, an estimate of the travel cost incurred per day is desirable. As was shown above, the travel cost required to produce one fishing day will vary depending on the length of the trip. In turn, the length of trip could be expected to depend on the distance to the site, the individual's income and other factors such as the individual's fishing experience. The underlying problem is whether the travel cost per day can be estimated given data on the distance to the fishing site, and the number of days spent at the site. Fortunately, the New York Anglers' Survey contained selected data on expenditures. The Anglers' Survey asked the following questions:

- What amount was spent on travel to and from each fishing location in each category:
  - food, drink and refreshments
  - lodging
  - gas and oil
  - fares on buses, airlines, etc.
  - Total expenditures on travel

- What amount was spent at each fishing location on:
  - food, drink and refreshments
  - lodging
  - gas and oil
  - guide fees
  - access and boat launching fees
  - Total expenditures at the site

The goal of the statistical analysis presented in this section is to utilize this expenditure data to obtain an estimated travel cost per mile per fishing day. If the travel costs associated with one fishing day can be estimated, then the data on days at a site can be successfully used as the dependent variable in a travel cost model. It was expected that the travel costs per mile per day at a site would vary depending on the length of trip. For example, if a fisherman were to travel 150 miles to reach a site, it is likely that he would spend a greater number of days at the site than if he only had to travel 50 miles to reach the site. The higher fixed costs that have to be incurred to reach the more distant fishing sites would result in these costs being incurred only if the number of days spent at the site were sufficient to offset the travel costs. For example, assume that out-of-pocket travel costs are ten cents per mile. If a 50 mile travel distance is associated with one-day trips, then the 100 miles traveled round trip would result in a total cost of $10 to yield one fishing day. The travel cost per mile per fishing day would be $10 ÷ (100 mile * 1 day) = $.10. If 100 mile travel distances (200 miles round trip) are typically associated with three-day trips, then the travel cost per mile per fishing day would be $20 ÷ (200 miles * 3 days) = $.033. This implies that the travel costs associated with producing one fishing day are 3.3 cents per mile for a three-day trip.

3.2.1 Per Mile Travel Cost Estimation Results

The equations used to estimate the per mile travel costs all had the same basic specification. Travel expenditures per day were expressed as a function of distance to the site, the individual's income, and the number of years the individual had been fishing:

Travel Expenditures per Day = B_1(Distance) + B_2(Income) + B_3(years fishing experience)

The coefficient B_1 on distance has the dimension of dollars per mile per day. If significant, B_1 can be used as an estimate of the travel costs per mile per fishing day. The data were disaggregated into subsets of visits to sites that were 0 to 75 miles, 0 to 150, 0 to 225, and greater than 225 miles away from the fisherman's residence. Equations using data on visits to sites 75 to 150 miles, and 150 to 225 miles were also estimated. Table 3-3 presents the estimation results using total travel expenditures per day as the dependent variable. These results are encouraging. The coefficient on the distance variable is highly significant in all equations except for visits to sites where the distance traveled is greater than 225 miles. However, this is not surprising in that trips of this length are more likely to be influenced by factors other than travel costs, in particular, income. As can be seen from Table 3-3, the income variable was significant only for the longer trips.

The regression equations in Table 3-3 also show the expected relationship between travel cost per mile per day and the distance traveled to the site. The average cost per mile per day is higher for the shorter trips, reflecting that trips of short distances likely are associated with fewer days spent at the site:

Table 3-3

Regression Results Using Total Site Travel Expenditures per day As the Dependent Variable

(t-values in parentheses)

Regression No.	Distance (t-value)	Income	Years Experience	Constant	R^2	Overall F
1. Sites 0 to 75 miles from Residence	.66E-01 (8.11)	.234E-01 (1.395)	1.28 (-1.77)	(2.67)	.077	24.22
2. Sites 0 to 150 miles from Residence	.55E-01 (9.78)	.153E-01 (.6999)	.418E-03 (.296E-01)	1.50 (2.44)	.067	32.63
3. Sites 0 to 225 miles from Residence	.4398E-01 (10.128)	.24E-01 (.9137)	.234E-01 (1.42)	1.3349 (1.956)	.0635	36.62
4. Sites greater than 225 miles from Residence	.544E-02 (.377)	.138 (2.38)	-.082 (-2.07)	6.95 (1.65)	.028	3.04
5. Sites 75 to 150 miles from Residence	.238E-01 (9.50)	.482E-01 (1.98)	.156E-01 (1.02)	2.59 (4.17)	.049	33.465
6. Sites 150 to 225 miles from Residence	.97E-01 (2.05)	.6376 (.37)	.132 (1.86)	-12.48 (-1.39)	.033	2.87

Distance Traveled to Site	Estimated Travel Costs (t-value)
0 - 75	**6.6¢** per mile per day (8.11)
0 - 150	**5.5¢** per mile per day (9.78)
0 - 225	**4.4¢** per mile per day (10.13)
greater than 225	**.05¢** per mile per day (0.38)

There is one anomaly in the estimated travel costs shown in Table 3-3. The regression equation #5 on trips of 150 to 225 miles shows an estimated per mile travel cost that is larger than those from the equations for visits of 0 to 75 and 75 to 150 miles. There may be a number of reasons for this result. One possible cause could be a clustering of trips with travel distances near the lower end of the 75 to 150 mile range; however, additional analysis of the data would be useful in interpreting this result. Still, the travel costs for the 0 to 75, the 0 to 150, and the 0 to 225 trip distance subgroups show the expected relationship and these regressions would not be as sensitive to the clustering of trip distances within each range. The results of these regressions show a declining relationship between trip distance and travel cost per mile per day.

A second set of regression equations were estimated using only oil and gas travel expenditures per fishing day rather than total travel expenditures. These costs may better represent the variable costs of traveling, since food and lodging would have to be provided on a trip of any distance. The same independent variables were used in the estimation. The results are shown in Table 3-4. Again the results are encouraging. The coefficients on the distance variables are significant in all equations, except for the visits to sites of greater distances:

Distance Traveled to Site	Estimated Oil & Gas Travel Costs (t-value)
0 - 75	**5.8¢** per mile per day (7.84)
0 - 150	**3.9¢** per mile per day (9.71)
0 - 225	**2.5¢** per mile per day (8.58)
greater than 225	**-.003¢** per mile per day (.36)

Table 3-4

Regression Results Using Expenditures on Oil and Gas

(t-values in parentheses)

Regression No.	Distance (t-value)	Income	Years Experience	Constant	R^2	Overall F
1. Sites 0 to 75 miles from Residence	.579E-01 (7.84)	.258E-01 (1.72)	-.467E-01 (-1.679)	.834 (1.935)	.078	23.09
2. Sites 0 to 150 miles from Residence	.39477E-01 (9.71)	.2527E-01 (1.515)	-.1069E-01 (-1.06)	1.46 (3.29)	.0717	33.016
3. Sites 0 to 225 miles from Residence	.248E-01 (8.58)	.2864E-01 (1.63)	.7488E-02 (-.689)	2.1665 (4.75)	.05	26.779
4. Sites greater than 225 miles from Residence	-.326E-03 (-.36E-01)	.104 (2.85)	-.4035E-01 (-1.59)	4.855 (1.827)	.03	3.21
5. Sites 75 to 150 miles from Residence	.1015E-01 (6.42)	.489E-01 (3.21)	-.0061 -.627)	2.626 (6.71)	.028	19.267
6. Sites 150 to 225 miles from Residence	-.372E-01 (-1.369)	.423E-01 (.726)	.952E-02 (.2335)	11.97 (2.335)	.0092	.798

A third set of regression equations were estimated using total costs (travel and on-site) divided by days at the site. These equations were estimated for comparison purposes and as a consistency check. These estimates include expenditures at the site and are not appropriate for use as travel costs. Still, these estimates are informative. The coefficient on the distance variable is still dimensioned in dollars per mile per day. Also, it is possible that site expenditures may be related to distance. If a greater distance is traveled, then more activities may be required to make the time spent at the site worth the incremental travel costs. Although this hypothesis is weak theoretically and is entirely dependent upon the marginal utility and cost of activities available at the site visited, it is easily tested with this data. The results of these regressions are shown in Table 3-5. Again, the coefficient on the distance variable was significant except for the longer trips and declined in magnitude as trips of longer duration were included:

Distance Traveled to Site	Estimated Total Costs (t-values)
0 - 75	**17.0¢** per mile per day (6.15)
0 - 150	**16.1¢** per mile per day (8.03)
0 - 225	**10.9¢** per mile per day (9.20)
greater than 225	**4.6¢** per mile-day (1.7)

Another result from the regressions presented in Table 3-5 worth noting is that income was a more important variable for explaining total costs per day than for explaining travel costs only. It seems intuitively plausible to have high recreation expenditures at the site correlated with high individual incomes.

3.2.2 Estimated Travel Costs: Conclusions

The results of the travel cost estimation are encouraging and indicate that reasonable estimates of travel costs to provide a fishing day can be obtained. As expected, these costs tended to vary with the length of trip. In most travel cost models, the per mile travel cost comes from a source such as the American Automobile Association's published estimates of average travel cost per mile. This travel cost per mile estimate

Table 3-5

Regression Results Using Total Travel and Site Expenditure per day* as the Dependent Variable

(t-values in parentheses)

Regression No.	Distance (t-value)	Income	Years Experience	Constant	R^2	Overall F	DF
1. Sites 0 to 75 miles from Residence	.17 (6.15)	.0136 (.232)	-.066 (-2.08)	3.57 (2.16)	.0676	13.91	576
2. Sites 0 to 150 miles from Residence	.0251 (1.58)	.227 (2.47)	.089 (1.41)	11.01 (2.47)	.0216	378	517
3. Sites 0 to 225 miles from Residence	.0465 (1.70)	.294 (2.64)	.01 (.1439)	4.90 (.611)	.0324	3.25	292
4. Sites greater than 225 miles from Residence	.654 (6.78)	.1739 (3.40)	-.827E-03 (-.0257)	10.56 (8.95)	.0305	20.33	1938
5. Sites 75 to 150 miles from Residence	.161 (8.03)	.1107 (1.31)	-.22E-01 (-.4452)	1.93 (.867)	.065	22.45	955
6. Sites 150 to 225 miles from Residence	.1089 (9.20)	.1158 (1.566)	.0187 (.416)	3.56 (1.856)	.0723	30.56	1176

*Dependent Variable is the individual's total expenditures on travel to the site (includes gas and oil, food and lodging in transit), plus the cost of lodging, food and activities at the site divided by the number of days spent at the site.

poses problems due to the large variability in per mile costs that results from the variability in age and type of vehicles (compact cars as compared to Winnebagos).[2] The estimates obtained from the regression equations reported in this section are based on reported expenditure data and, although subject to error, are probably no worse than those used in other travel cost studies. These estimates may even be preferred in that they may better represent the individual's perceived travel costs since they are based on expenditure data supplied by the respondent; and, it is the perceived travel costs that individuals use when making their site selections.

The estimation results are summarized in Table 3-6. The range of estimates for travel costs per day for sites of different distances was quite narrow. The per mile total travel costs ranged from 6.6 cents per mile per day for nearby sites (0 to 75 miles) to 4.4 cents per mile per day as more distant sites were included in the sample (0 to 225 miles). The estimates for only the oil and gas portion of travel costs were slightly less, ranging from 5.8 to 2.5 cents per mile per day.

3.3 TRAVEL COST MODEL ESTIMATION

Several different techniques were considered for use in estimating a relationship between travel costs and fishing days. The data set available for use in this project is different from the data sets typically used in travel cost models. To briefly review, the data set contains information on individuals, the distances from the individuals' home to each of the 24 sites, and the number of days that the individual spent at each of the 24 sites. The fewest number of individuals visiting any site was 30. In estimating the site demand function, the typical travel cost model would only use data on individuals that have actually visited the site. This would result in observations on a sample of 30 individuals being available for the least visited site. However, using data on only those individuals that have actually visited the site ignores a substantial amount of information, namely the travel distance to the site and characteristics of the individuals that did not visit the site. For many of these individuals, the price in terms of travel costs to sites not visited may have been too high relative to the costs of visiting other sites. This information is pertinent to the analysis and should not be omitted from the estimation. As a result, it is

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[2] For example, Vaugan and Russell (1982) use the AAA estimate of 7.62 cents per mile.

Table 3-6

Summary of Estimated Expenditures per Mile per Day
(t-values in parentheses, units are cents per mile per fishing day)

Distance to Site	Estimated Total Travel Costs	Estimated Oil and Gas Travel Costs Only	Estimated Total Costs: Travel and Site
0 to 75 miles	6.6 (8.11)	5.8 (7.84)	17.0 (6.15)
0 to 150 miles	5.5 (9.78)	3.9 (9.71)	16.1 (8.03)
0 to 225 miles[1]	4.4 (10.13)	2.5 (8.58)	10.9 (9.20)
Greater than 225 miles	.05 (.34)	-.003 (.36)	4.6 (1.7)

[1] These travel cost estimates for trips of 0 to 225 miles were used in Chapter 5.0.

desirable that the travel cost models for each site be estimated using the entire data set. This would encompass those individuals in the sample that visited the site, as well as those that did not.

A data set that contains observations on individuals who purchased the commodity (i.e., made a trip to the site), as well as on individuals who did not purchase the commodity, is termed a "limited" data set.[3] The data set is "limited" in that the dependent variable is not observable over the entire range. In this case, the dependent variable is fishing days at each site and is observable only when a trip to that site has been made. Therefore, the dependent variable is observable only when it is greater than zero. The regression model is:

$$D = BX + u; \tag{3.1}$$

where "D" represents the number of days spent at the site. D is observed only if $D > 0$. Therefore, the model is:

$$D = BX + u \text{ if } BX + u > 0, \text{ which implies } u > -BX$$

or (3.2)

$$D = 0 \qquad \text{if } BX + u \leq 0$$

Applying ordinary least squares (OLS) regression techniques to only those observations for which $D > 0$ results in biased estimates. The residuals in this equation will not satisfy the OLS assumption that $E(u) = 0$. If some specific assumptions are made about the distribution of the residuals, then maximum likelihood techniques can be used to estimate the parameters. If it is assumed that u has a normal distribution with mean zero and variance σ^2, then the joint distribution of the observations is:

$$L = \prod_1 \frac{1}{\sigma} f\left(\frac{D_i - BX_i}{\sigma}\right) \cdot \prod_2 F\left(\frac{-BX_i}{\sigma}\right) \tag{3.3}$$

3 This discussion follows Maddala (1977), pp. 162-164.

where $f(\cdot)$ is the standard normal density function and $F(\cdot)$ is the cumulative normal density. The first term corresponds to those individuals for which $D_i > 0$ and therefore is known. The second term corresponds to those individuals for which all that is known is that $D_i \leq 0$. The earliest application of this technique was by Tobin (1958).

The use of OLS techniques rather than the maximum likelihood techniques discussed above will result in biased estimates of the coefficients. If OLS is applied to the data and $D_i = 0$ is used for those individuals who did not visit the site, there will be many non-visitors with a resulting concentration of observations at $D_i = 0$. The absence of any negative D_i's in the sample will tend to keep the estimated regression equation above the zero axis over the relevant range of the X's, but it will also tend to flatten the estimated curve. This results in the estimated number of days spent at the site being underestimated for individuals with a low travel price (i.e., short distance between the site and individual), and overestimated for individuals with a higher travel price.

A TOBIT procedure is recommended to correct for this bias. The TOBIT analysis takes into account both the individual's likelihood of visiting a given site and the number of days spent at the site, given that the individual decides to visit the site. These two values taken together can be used to calculate the expected value of days at each site for each individual. The TOBIT procedures also produce consistent estimates of the regression coefficients in equation 3.1. In this analysis, both TOBIT and OLS estimates of the regression coefficients are derived and compared.

A separate travel cost equation for each of the 24 sites was estimated. In each case, the dependent variable is the number of days spent at the site. The independent variables were the distance to the site, the individual's income, and the individual's years of fishing experience. Distance to the site rather than an actual travel cost estimate was used as an independent variable to allow for easy sensitivity analysis around the estimated per mile travel cost. If information on the marginal value of time (e.g. wage rates) across the individuals in the sample had been available, then it might have been desirable to include an estimate of actual travel costs and actual time costs to determine relative influence of each cost on the willingness to take a trip. Since both the out-of-pocket value of time components of travel costs are expressed on a per mile basis in this analysis, using distance in miles as the independent variable provides the most general formulation.

Crocker et al., 1981) have been very low, an estimate that is biased on the high side, if still found to be low, should provide useful policy information.

3.3.1 TOBIT Procedures Applied to Total Fishing Days

The TOBIT procedure in the SHAZAM econometric software package was used to estimate the model. Table 3-7 presents the estimated regression coefficients obtained by using this TOBIT procedure and total fishing days at a site as the dependent variable. Table 3-7 shows that the distance variable was highly significant in most of the equations. The coefficients on the distance variable were significant at the 1 percent level in eighteen out of the twenty-three estimated equations. The distance variable was not significant or had the wrong sign in the equations for sites 10, 16 and 20.[6] Inspection of these sites showed that the total number of fishing days at these sites was in the lower half of the data set. The coefficients on the income and the years of fishing experience variables were generally not significant. The R-squares were low, typically varying between .01 and .10 for those equations where the distance variable was significant. While low, these R-squares are not atypical for travel cost models.[7]

The regression coefficients in the TOBIT model should be interpreted a little differently than conventional OLS regression coefficients. In the TOBIT procedure, an index "I" is created which is a function of the independent variables, I = XA; where A is a vector of normalized coefficients:

$$I_n = A_0 + A_1 X_{1n} + A_2 X_{2n} + \ldots + A_k X_{kn}; \qquad (3.4)$$

where I_n is the value of the index for the n^{th} individual given the values of the X_k's for that individual. These A_k normalized coefficients can be transformed into estimates of the regression coefficients - the Bi's - by multiplying the Ai's by the calculated standard error of the estimate:

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6 Also, the equation for site 13 was not estimated due to an error in the program that merged the distance data and the site characteristics data, the distances to site 13 were inadvertently entered as zeros. The merging of the data sets involved two extremely large data bases and was expensive. It was decided not to correct this error until it was determined to be significant.

7 For example, see Brown and Mendelsohn (1984) and Desvousges, Smith and McGivney (1983).

Table 3-7

Travel Cost Model Using Total Days as the Dependent Variable and Estimated with a TOBIT Procedure
(t-values in parentheses)

Site #	Distance	Income	Years Fishing	Constant	R^2*
1	-.3946 (7.71)	-.0727 (.19)	-.2661 (1.20)	-10.457 (1.25)	.083
2	-2752 (8.32)	-.4038 (1.67)	.1052 (.88)	-1.5800 (.26)	.077
3	-.0780 (3.52)	.1205 (.76)	-.0302 (.30)	-24.371 (5.30)	.0018
4	-.1794 (6.51)	.0928 (.55)	-.1008 (.95)	-10.915 (2.58)	.035
5	-.1772 (5.63)	-.1298 (.56)	.1254 (5.63)	-25.871 (4.32)	.06
6	-.8122 (7.92)	.1421 (.28)	-.8122 (7.92)	1.4610 (.11)	.074
7	-.0726 (2.40)	.0843 (.53)	-.0726 (2.40)	-26.931 (5.22)	.009
8	-.2350 (5.72)	.0969 (.40)	-2350 (5.72)	-25.511 (3.59)	.077
9	-2877 (6.34)	2334 (.99)	.4359 (2.90)	-38.819 (5.43)	.079
10	.1266 (2.62)	-.5379 (2.36)	.1250 (1.14)	-53.252 (7.46)	.001
11	-.0777 (3.38)	-.0304 (.26)	.0038 (.05)	-16.996 (4.80)	.011
12	-.1638 (3.18)	.2017 (.84)	-.0345 (.23)	-41.044 (5.44)	.006
14	-.1304 (3.81)	.3542 (2.47)	.1484 (1.59)	-31.192 (5.77)	.013
15	-.0842 (3.11)	.0903 (.87)	.0363 (.58)	-18.249 (4.73)	.007

*Note: R^2 between observed and predicted values.

Table 3-7

Travel Cost Model Using Total Days as the Dependent Variable and Estimated with a TOBIT Procedure

(continued)

Site #	Distance	Income	Years Fishing	Constant	R^2*
16	-.0024 (.11)	-.2005 (1.75)	-.0432 (.73)	-19.036 (5.56)	.0006
17	-.1915 (3.53)	-.0731 (.35)	-.0072 (.06)	-26.191 (3.65)	.0119
18	-.2301 (3.07)	.0944 (.28)	-.0174 (.09)	-55.701 (5.22)	.007
19	-.3893 (10.24)	.6607 (4.75)	.0915 (1.04)	-9.9139 (2.21)	.058
20	.0543 (1.12)	-.1903 (.66)	.2764 (1.78)	-68.586 (7.94)	.004
21	-.1912 (4.25)	-.0816 (.43)	.1727 (1.59)	-27.370 (4.41)	.0117
22	-.3626 (6.62)	-.0584 (.37)	-.0794 (.90)	.2548 (.05)	.038
23	-.4553 (10.85	-.1374 (.95)	.1884 (2.31)	1.6300 (.38)	.098
24	-.3262 (10.04)	.0428 (.32)	-.0935 (1.22)	.1331 (.03)	.027

Note: R^2 between observed and predicted values.

Figure 3-1

Expected Relationship Between the OLS Estimates, TOBIT Estimates, and the TOBIT Generated Expected Values[1]

Figure 4-1a - Standard TOBIT, OLS Relationship

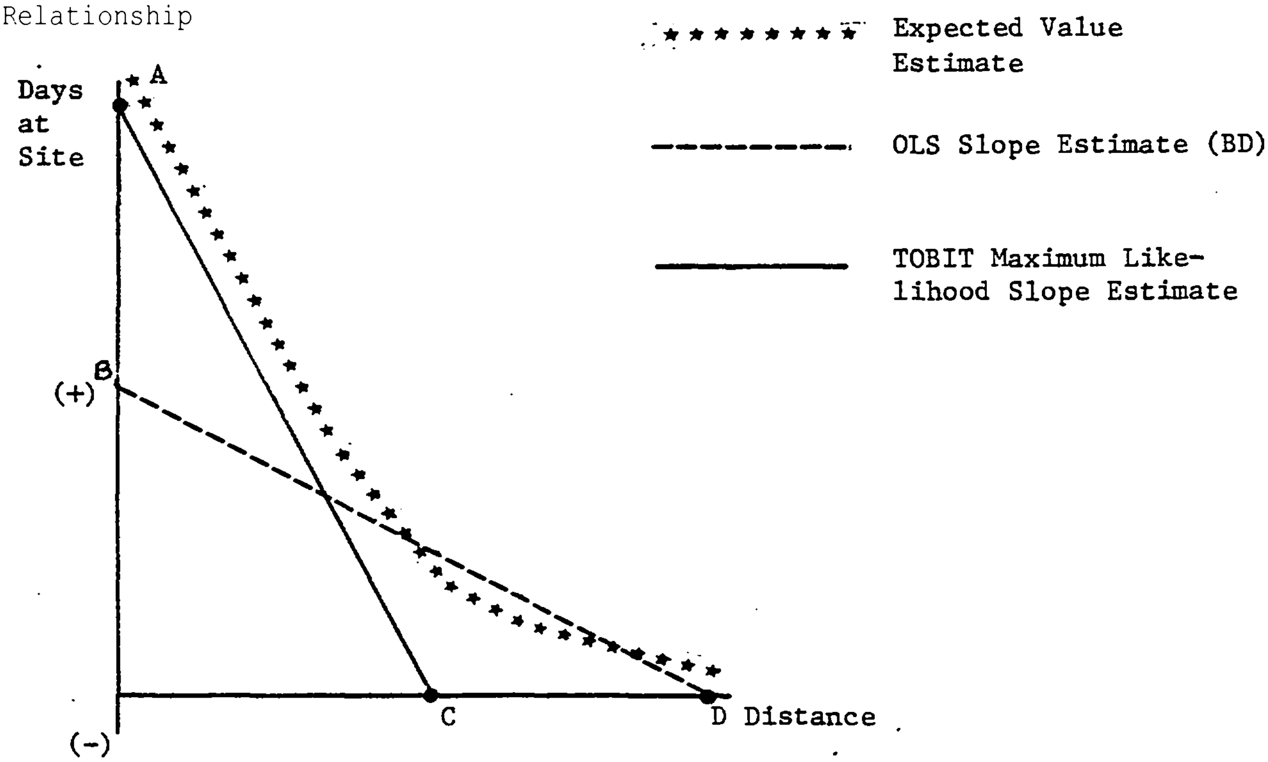
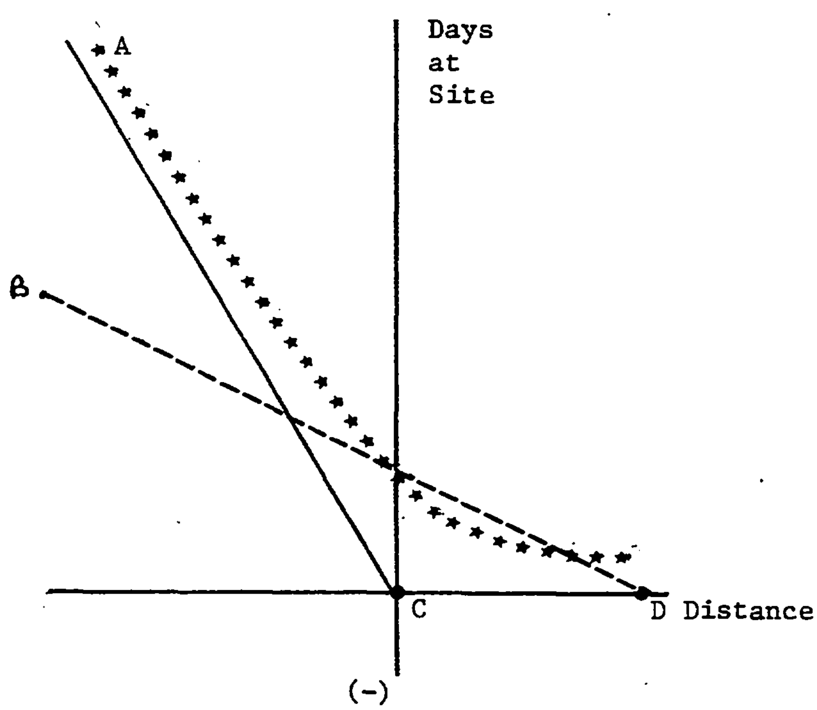


Figure 4-1b - Relationship when the probabilities of an individual visiting the site are less than .5 for all distances



[1] This figure is similar to Figures 3a and 3b in Tobin (1958).

- σ is the standard error of the dependent variable;
- f (·) and F (·) are the marginal and cumulative normal density functions.

As is shown in Figure 3-1, this method of calculating the expected value locus results in a nonlinear relationship. The expected value locus will always be above the TOBIT maximum likelihood equation (i.e., segment AC). At the left where the probabilities of visiting a site are high, the expected value locus will approach AC asymptotically. At the right where the probability of visiting a site approaches zero, the expected value locus will approach the line segment CD, which will be the horizontal axis in cases where the limiting value is zero.

Given the above explanation, some further analysis of certain peculiarities of the TOBIT regression results are possible. An examination of the coefficients estimated for site 1 in Table 3-7 shows that all of the coefficients are negative. This fact combined with the realization that the values of all the independent variables are positive results in any predicted number of fishing days from this model being negative. However, this result is consistent with the TOBIT interpretation presented above. There are two factors that must be considered when interpreting this outcome. First, the regression coefficients are used to calculate an index that in turn is used to calculate the probability of an individual taking a trip. This index is positive whenever the probability of taking a trip exceeds fifty percent and is negative whenever the probability is less than fifty percent.[9] This result for site 1 indicates that the probability of any one individual taking a fishing trip to that particular site is less than .5; however, the expected value for fishing days will still be positive. This outcome is illustrated in Figure 3-1b.[10] A second point that should be considered when interpreting the TOBIT coefficients for site 1 is the large standard errors of the coefficients on the non-distance variables. These make the actual intercept in Figure 3-1 very uncertain.

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[9] See Tobin (1958), page 34 and Goldsmith (1983) footnote 19, page 39.

[10] A similar result was found by Deegan and White (1976) where their TOBIT regression coefficients only yielded negative values for the dependent variable over the entire range of X_1, with the other X_i held constant at their means.

3.3.2 Ordinary Least Squares Applied to Total Fishing Days

In spite of the fact that OLS estimates are biased, it was felt that applying OLS to the data sets could provide useful information on the strength of the relationship between fishing days and distance to the site. Also, the OLS estimates would provide a useful point of comparison since there is an explicit theoretic prior expectation of the relative magnitudes of the OLS and TOBIT regression coefficients.

The OLS estimates are presented in Table 3-8. As in the TOBIT analysis, only sites requiring trips of less than 225 miles one way were included in the data set. The results in Table 3-8 show that the distance variable was highly significant variable in most of the equations. The coefficients on the distance variable were significant at the 1 percent level in eighteen out of the twenty-three estimated equations. The distance variable was not significant for sites 3, 10, 12, 16 and 20. The income and the years of fishing experience variables were generally not significant. The R-squares were low, typically varying between .01 and .06 for those equations where the distance variable was significant.

Comparing the OLS results to the TOBIT results, the magnitudes of the coefficients conform to theoretic expectations. The absolute magnitudes of the TOBIT coefficients are greater than the OLS estimated coefficients. Also, the calculated t-values and R-squares were higher for the TOBIT equations.

3.4 SECOND STAGE ANALYSIS OF THE CHARACTERISTICS OF FISHING SITES

The coefficients of a travel cost model using both TOBIT and OLS procedures were estimated in Section 3.3. As was discussed in Chapter 1.0, these travel cost models do not explicitly take into account site characteristics. Travel cost models do estimate the travel and time costs that an individual is willing to pay to visit a site. These willingness-to-pay amounts can be calculated from the coefficients on the independent variables in the visitation equation for each site. It seems likely that sites with more desirable recreational characteristics, such as fishing opportunities and catch rate, would attract fishermen from further distances. This fact should show up in the relative magnitudes of the estimated coefficients on the distance variable in the site equations. Also, the participation models estimated in Section 3.1 showed the number of visitor days to be positively related to site characteristics such as acres of ponds and total catch rate.

Table 3-8

Travel Cost Model Using Total Days as the Dependent Variable and Estimated by Ordinary Least Squares
(t-values in parentheses)

Site #	Distance	Income	Years Fishing	Intercept	R^2
1	-.0158 (6.72)	-.0066 (.41)	-.0139 (1.48)	3.3441 (6.86)	.0468
2	-.0178 (6.45)	-.0254 (1.84)	.0075 (.93)	3.3922 (6.77)	.0445
3	-.0012 (1.02)	-.0027 (.32)	.0008 (.16)	.4533 (1.73)	.0012
4	-.0076 (5.92)	.0036 (.52)	-.0007 (.18)	1.21 (5.43)	.033
5	-.0133 (6.06)	-.0074 (.57)	.0114 (1.52)	2.0050 (5.00)	.0369
6	-.0235 (5.60)	-.0047 (.23)	.0082 (.69)	3.4523 (4.91)	.0303
7	-.0104 (3.51)	-.0060 (.25)	.0157 (1.89)	1.5810 (3.23)	.0155
8	-.0347 (6.76)	-.0065 (.25)	.0014 (.09)	5.5683 (6.64)	.0436
9	-.0168 (5.82)	-.0082 (.57)	.0174 (2.07)	2.0850 (4.62)	.0355
10	.0052 (1.18)	-.0167 (1.28)	.0109 (1.43)	-.1924 (.36)	.0044
11	-.0040 (3.38)	-.0021 (.37)	-.0016 (.49)	.75 (4.13)	.0118
12	-.0064 (1.59)	-.0048 (.26)	-.0076 (.70)	1.4612 (2.46)	.0031
13	NA	NA	NA	NA	NA
14	-.0157 (3.96)	.0088 (.58)	.0112 (1.27)	1.9952 (3.33)	.0172
15	-.0091 (3.40)	.0050 (.63)	-.0019 (.41)	1.32 (3.83)	.0113
16	-.0010 (.58)	0.0054 (1.00)	-.0005 (.16)	.4222 (1.82)	.0014

Table 3-8

Travel Cost Model Using Total Days as the Dependent Variable and Estimated by Ordinary Least Squares

(t-values are in parentheses)

(continued)

Site #	Distance	Income	Years Fishing	Intercept	R^2
17	-.0182 (2.94)	-.0158 (.98)	.0058 (.61)	2.4106 (3.38)	.0102
18	-.0229 (3.19)	-.0033 (.13)	.0257 (1.68)	2.1425 (2.35)	.0126
19	-.0439 (6.63)	.0717 (2.44)	.0335 (1.94)	3.9322 (4.23)	.0498
20	.0022 (1.08)	-.0093 (.93)	.0126 (2.15)	-.1677 (.55)	.0062
21	-.0137 (2.64)	-.0310 (1.59)	.0281 (2.44)	1.9496 (2.74)	.0152
22	-.0180 (5.38)	-.0153 (1.43)	-.0023 (.36)	2.3041 (5.79)	.0291
23	-.0486 (7.56)	-.0719 (2.27)	.0248 (1.33)	6.5822 (6.93)	.0579
24	-.0316 (5.52)	-.0155 (.53)	-.0156 (.91)	5.2824 (6.15)	.029

This section presents the results from regressing the coefficients from each site equation on selected characteristics of that site. Two site characteristics were used: fishable acreage and total catch rate. The equation that was estimated is shown below:

$$B_{ij} = A_0 + A_1\,(\text{Acres})_j + A_2\,(\text{Catch Rate})_j$$

where B_{ij} is the i^{th} parameter (either a coefficient or intercept from the j^{th} site equation. Two parameters were used as the dependent variable in this second stage. The first was the coefficient on the distance variable (i.e., B_{1j}), the second was the intercept. The demand curve intercept was defined as:

$$B_{2j}\,(\text{Mean Income Value}) + B_{3j}\,(\text{Mean Experience Value}) + B_{4j}.$$

This composite variable represents the intercept of a demand equation relating fishing days to distance, holding the other variables constant at their mean values. It would have been possible to estimate each coefficient and intercept as a function of the site characteristics; however, the income and experience variables were not significant in most of the site equations. As a result, these coefficient estimates have large standard errors and, at best, are imprecisely estimated. This would make statistically significant estimates of the effects of the site characteristic levels on these coefficients unlikely and the results hard to interpret. Given this situation, only the above composite intercept was regressed against site characteristics.[11] Since this intercept is the actual demand curve intercept, this was felt to be appropriate.

The results of regressing both the coefficient on the distance variable and the intercept against two site characteristics - net park areas and total catch rate -- are shown in Table 3-9a. In addition to that specification two other specifications were estimated. The results of these are shown in Table 3-9b. The generalized least squares procedure discussed in Chapter 1 was used in both instances. Table 3-10 presents similar GLS estimated equations for the parameters from the OLS estimated travel cost equations.

In Tables 3-9 and 3-10, the site characteristics have t-values that are small. Still, a t-value of 1.27 is significant at the 10 percent level for a one-tailed test and 20 percent

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[11] No attempt was made to regress the individual coefficients on income and experience against the site characteristics. Only this composite intercept was regressed.

Table 3-9

Second Stage GLS Runs on the TOBIT Estimated Parameters from the Total Fishing Day Equations

(t-values)

a. Base Equations

Dependent Variable	Net Park Acres	Total Catch Rate	Constant	R^2
Coefficient on Distance Variable	$-.692 \times 10^{-5}$ (1.80)	-.007 (1.01)	-.116 (-1.27)	.161
Intercept	$.597 \times 10^{-3}$ (1.27)	4.81 (2.47)	45.01 (10.15)	.225

b. Additional Trial Specifications

Dependent Variable	Acres less than 1500 feet Elevation	Warm Water Acres	Two Story Acres	Total Catch Rate	Constant	R^2
Coefficient or Distance Variable	$-.519 + 10^{-5}$ (1.36)			-.0056 (.2907)	-.129 (1.89)	.108
Intercept		$.623 \times 10^{-3}$ (1.38)	$.211 + 60^{-3}$ (.449)	3.07 (1.13)	32.14 (3.15)	.134

Table 3-10

GLS Runs on the OLS Parameters from the Total Day Equations

Dependent Variable	Net Park Acres	Total Catch Rate	Constant	R^2
Coefficient on the Distance Variable	$-.852 \times 10^{-6}$ (1.91)	$-.254 \times 10^{-2}$ (1.48)	$+.583 \times 10^{-2}$ (.797)	.178
Intercept	$.135 + 10^{-4}$ (2.44)	.253 (1.04)	$.740 \times 10^{-1}$ (.072)	.235

for a two-tailed test. Although they are not significant at the highest levels (e.g. 1 percent), these estimates represent the best information currently available and meet modest statistical criteria.

3.5 TRAVEL COST MODEL ESTIMATES: CONCLUSIONS

The statistical results presented in this section show a strong relationship between visitor days at a site and the travel distance to the site. The analyses performed to date provide estimates that can be used to estimate the consumer surplus derived from each fishing site; however, only the most basic specifications have been estimated and additional analyses certainly would be desirable.

There are several specific areas where additional analysis could prove beneficial. One of these would be the examination of alternative functional forms including semi-log and Box-Cox specifications. A second issue warranting additional analysis would be the opportunity cost of time. To examine this second issue, an estimate of the individual's marginal valuation of time is needed. Most often, the individual's wage rate is used as an estimate of the value of time. Unfortunately, the Anglers' Survey does not include information on the individual's wage. It would be possible, however, to perform an analysis similar to that contained in Section 7.4 of Desvousges, Smith and McGivney (1983).

Desvousges et al. used a model that predicts the wage rate given the individual's annual income, occupation and related characteristics. Desvousges et al. found the variation in estimated wage rates from the mean wage level to be approximately 50 percent.[12]

Given the potential magnitude of other errors in the model, the error due to not capturing differences in individual's marginal valuation of time does not seem overwhelming, but it also should not be minimized. The present formulation of the model where distance rather than a specific travel cost is entered into the model allows alternative cost per mile values to be calculated using varying travel and time costs.

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[12] The mean wage was $5.44 per hour. The low wage was $2.75 for female farmers and the high was $7.89 for male professional workers.

Another important issue concerns the current inability to estimate a separate model for brook trout fishing days. The TOBIT procedures applied to brook trout fishing days failed to converge on a set of coefficients for most of the sites because of too few non-zero observations. This possibly could be remedied by redefining the sites and using alternative numerical techniques. Since the brook trout fish population is the fishery most threatened by acid deposition, a separately estimated brook trout travel cost model could be useful.

4.0 RECREATIONAL FISHING RESOURCE VALUATION

There are several procedures that can be used to provide estimates of the value of damages (i.e., reduced benefits) to recreational fishing in the Adirondacks from current levels of acidification. Section 3.3 discussed the relationships between demand curves based on OLS estimated regression coefficients, TOBIT estimated regression coefficients, and the expected value locus calculated from the TOBIT coefficients. A consumer surplus estimate associated with each of the sites can be calculated using each of these demand curves. Of these three options, the most appropriate curve to use for estimating the consumer surplus is the TOBIT based expected value locus, since this estimate takes into account both the probability of visiting the site and the estimated number of days at a site given that a trip is taken. In addition to the travel cost model, estimates of damages from acidification can be derived from the participation model presented in Section 3.1.

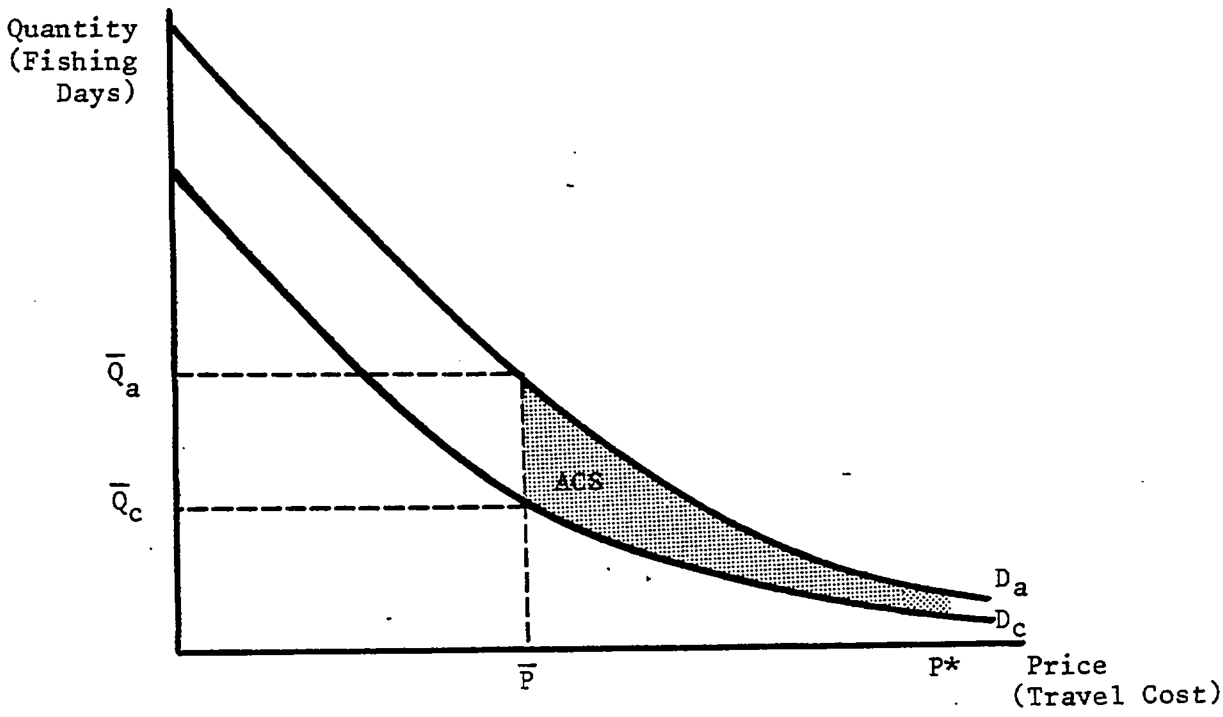
The reduction in benefits due to the effects of acidification can be estimated by examining the difference between the consumer surplus estimates in the current state and the pristine, pre-acidification state.[1] Figure 4-1 illustrates this benefits calculation. The shaded area in Figure 4-1 is a measure of the dollar value of the damages that have resulted from acidification.

4.1 ESTIMATE OF DAMAGES FROM ACIDIFICATION USING THE TRAVEL COST MODEL

Estimates of the value of each site, using the travel cost model results, were obtained by using the routine in the SHAZAM econometrics software package that produces the expected value locus. These expected value curves were estimated holding the values of

[1] This consumer surplus measure is termed the Marshallian consumer surplus. It is not a perfect welfare measure, but it is an adequate approximation for this application. Other consumer surplus measures are available, but Freeman (1979) concludes that the differences among these measures are "small and almost trivial for most realistic cases."

Figure 4-1
Measurement of the Reduction in Consumer Surplus
Resulting from Acidification



- D_c is the demand curve in the current situation where acidification has reduced the fishing opportunities available at the site.
- D_a is the demand curve given that there is no acidification.
- ACS is the change (i.e., reduction) in consumer surplus due to acidification.

the income variable and fishing experience variable constant at the means of the sample. This resulted in a schedule for each site that shows the increase (decrease) in the expected number of fishing days the "average" individual would spend at a site as his distance from the site decreases (increases), other things held constant.

The estimated total willingness to pay and consumer surplus for each site is shown in Table 4-1. These are based on an out-of-pocket travel cost estimate of 4.4 cents per mile (from Table 3-6) and an opportunity of time cost of 9.06 cents per mile. The time cost was based on an assumed average driving speed of 40 miles per hour, and the deflated mean hourly wage of a sample of fishermen from Desvousges et. al. (1983). The time cost was calculated as being two thirds of the wage rate to reflect the fact that some individuals may obtain some enjoyment from the drive and, therefore, time in transit should not be valued at the full wage rate. Table 4-1 shows the value for the current recreational fishing experience in the Adirondacks to be 261 million dollars per year.

The next step in the analysis is to obtain an estimate of the losses that may have resulted from current levels of acidification. The second stage equations (shown in Table 3-9) that regressed the TOBIT regression coefficient on the characteristics of the sites can be used to show how the value of the resource has changed due to increased acidification. These estimates are based on analyses conducted by Dr. Joan Baker as part of the National Acid Precipitation Assessment Program (NAPAP). These estimates are based on research that is still in progress.[2] Table 4-2 shows some sites to have experienced greater levels of acidification than other sites. This is due to a number of factors which may include differing amounts of acid deposition and varying susceptibility of the lakes in a site.

The reductions in fishing opportunities shown in Table 4-2 can be translated into an estimated economic loss by using the site characteristic equations from Table 3-9. These characteristic equations can be used to calculate how the TOBIT estimated regression coefficients change as a result of these site characteristic changes. The new TOBIT regression coefficients are then used to estimate a new expected value locus. New willingness-to-pay estimates can be calculated from these new curves. The difference be-

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[2] Caveats to these estimates are presented in the Appendix.

Table 4-1

Current Values Per Year For

Recreational Fishing in the Adirondacks

Site	Expenditure[1]	Consumer Surplus[1]	Total Willingness To Pay[1]	Total Willingness To Pay Per Fishing Day	Consumer Surplus Per Fishing Day
1	7,294.5	3,033.0	10,327.5	107	31
2	8,483.8	2,912.6	11,396.4	104	26
3	4,157.5	1,267.5	5,425.0	118	27
4	3,228.4	1,489.8	4,718.2	97	31
5	5,870.5	2,510.4	8,380.9	98	29
6	6,586.6	4,038.1	10,624.7	105	40
7	7,784.2	4,373.6	12,157.8	107	38
8	13,615.6	6,334.5	19,950.1	96	30
9	5,679.1	2,934.3	8,613.4	96	32
10	(*)	(*)	(*)	(*)	
11	2,415.6	1,147.1	3,562.7	75	24
12	6,569.0	3,698.7	10,267.7	103	37
13	N.A.	N.A.	N.A.	N.A.	N.A.
14	7,557.9	3,054.7	10,612.6	80	23
15	4,417.9	2,120.4	6,538.3	75	24
16	2,610.1	2,082.4	4,692.5	88	39
17	5,649.7	2,181.0	7,830.7	66	18
18	7,469.4	3,785.0	11,254.4	64	21
19	18,583.9	10,285.3	28,869.2	79	28
20	(*)	(*)	(*)	(*)	(*)
21	8,881.9	3,982.7	12,864.6	71	22
22	3,691.4	3,053.6	6,745.0	78	35
23	18,429.6	17,460.4	35,890.0	85	41
24	16,657.0	13,400.6	30,057.6	81	36
TOTAL	165,580.3	95,146.1	260,726.4	85	31

[1] Thousands of 1984 dollars per year

* These sites had a positive coefficient on the travel cost variable.

Table 4-2

Losses of Fishable Areas of Lakes Due to Acidification

Site	Total Acreage (km^2)	Percent Reduction Moderate Loss Estimate Scenario 1	High Loss Estimate Scenario 2
1	27.023	0.0	0.0
2	(*)	(used site 6 estimates)	
3	61.510	.1%	4.3%
4	22.595	2.2%	32.0%
5	28.126	.1%	.1%
6	7.008	5.3%	10.6%
7	145.445	.2%	8.6%
8	16.591	1.0%	19.5%
9	23.404	.3%	.3%
10	55.165	0.0	16.7%
11	12.545	5.1%	10.4%
12	22.146	.2%	32.0%
13	71.019	17.7%	21.3%
14	25.750	7.5%	7.5%
15	39.235	.2%	.2%
16	14.529	.2%	2.7%
17	36.319	.5%	3.4%
18	30.654	1.1%	3.3%
19	4.654	0.0	0.0
20	62.679	12.0%	27.7%
21	27.265	.6%	7.4%
22	17.411	20.2%	28.3%
23	125.79	0.0	0.0
24	(*)	(used site 23 estimates)	

* These sites lie outside the Adirondack Park boundaries. Dr. Baker's data set did not have information on these sites.

tween the original willingness-to-pay or consumer surplus estimates represents the change in the value of the experience due to the change in characteristics; in this case, fishable acres of water.

Two site characteristics were incorporated in the TOBIT analyses presented in Section 3.4. They were net fishable acres and the catch rate in the remaining fishable acres at that site.[3] It was assumed that the percentage change in net fishable acres due to acidification is the same as the percentage change in total fishable acres estimated by Dr. Baker. How acidification at these levels influences the catch rate at a site is unknown. As a result, several assumptions regarding the catch rate were made. Tables 4-3 and 4-4 show how the value of the recreational fishing resource changes assuming that the catch rate is unaffected by whatever acidification has occurred. Tables 4-5 and 4-6 assume that acidification reduces the average catch rate experienced by fishermen at the site by the same proportion as fishable acres. The resource value changes presented in Tables 4-3 through 4-4 can be summarized as follows:

1) The estimated current value of the recreational fishing sites in terms of total willingness to pay is 260.7 million dollars per year. The estimated current consumer surplus is 95.1 million dollars.

2) Using the moderate acreage loss estimate and assuming no change in catch rates, acidification is estimated to have resulted in a decline in the resource value of 1.8 million dollars per year and reduced consumer surplus of .7 million dollars per year.

3) Using the high acreage loss estimate and assuming no change in catch rates, acidification is estimated to have resulted in a decline in the resource value of 10.4 million dollars per year and a reduced consumer surplus of 4.6 million dollars per year.

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[3] Estimates were available for the amount of lake area that would no longer support a fish population, but catch rates at remaining fishable lake acreage might also be reduced by acidification.

Table 4-3

Valuation of Resource Losses Due to Acidification: Moderate Acreage Loss Scenario

($\$ \times 10^3$ per year, 1984 dollars)

Site	Current Willingess To Pay	Willingness to Pay Given No Acidification	Losses	Current Consumer Surplus	Consumer Surplus Given No Acidification	Losses
1	10,330	10,330	0	3,030	3,030	0
2	11,400	11,570	170	2,910	2,960	50
3	5,420	6,150	730	1,270	1,470	200
4	4,720	4,860	140	1,490	1,540	50
5	8,380	8,380	0	2,510	2,510	0
6	10,620	10,930	310	4,040	4,160	120
7	12,160	12,190	30	4,370	4,390	20
8	19,950	19,970	20	6,330	6,340	10
9	8,610	8,620	10	2,930	2,940	10
10	(*)	(*)	(*)	(*)	(*)	(*)
11	3,560	3,570	10	1,150	1,160	10
12	10,270	10,270	0	3,700	3,700	0
13	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
14	10,610	10,760	150	3,050	3,100	50
15	6,540	6,600	60	2,120	2,140	20
16	4,690	4,690	0	2,080	2,080	0
17	7,830	7,850	20	2,180	2,190	10
18	11,250	11,270	20	3,780	3,790	10
19	28,870	28,870	0	10,280	10,280	0
20	(*)	(*)	(*)	(*)	(*)	(*)
21	12,860	12,900	40	3,980	3,990	10
22	6,740	7,140	400	3,050	3,240	190
23	35,890	35,890	0	17,460	17,460	0
24	30,060	30,060	0	13,400	13,400	0
TOTALS	260,700	262,530	1,830	95,150	95,880	730

* These sites had a positive coefficient on the travel cost variable.

Table 4-4

Valuation of Resource Losses Due to Acidification: High Acreage Loss Scenario

($\$ \times 10^3$ per year, 1984 dollars)

Site	Current Willingess To Pay	Willingness to Pay Given No Acidification	Losses	Current Consumer Surplus	Consumer Surplus Given No Acidification	Losses
1	10,330	10,330	0	3,030	3,030	0
2	11,400	13,030	1630	2,910	3,400	490
3	5,420	6,190	770	1,270	1,490	220
4	4,720	5,670	950	1,490	1,850	360
5	8,380	8,380	0	2,510	2,510	0
6	10,620	10,980	360	4,040	4,180	140
7	12,160	13,320	1,160	4,370	4,830	460
8	19,950	22,240	2,290	6,330	7,150	820
9	8,610	8,620	10	2,930	2,940	10
10	(*)	(*)	(*)	(*)	(*)	(*)
11	3,560	3,600	40	1,150	1,160	10
12	10,270	10,940	670	3,700	3,960	260
13	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
14	10,610	10,760	150	3,050	3,100	50
15	6,540	6,600	60	2,120	2,140	20
16	4,690	4,790	100	2,080	2,130	50
17	7,830	7,920	90	2,180	2,200	20
18	11,250	11,280	30	3,780	3,800	20
19	28,870	28,870	0	10,280	10,280	0
20	(*)	(*)	(*)	(*)	(*)	(*)
21	12,860	13,180	320	3,980	4,080	100
22	6,740	7,290	550	3,050	3,320	270
23	35,890	35,890	0	17,460	17,460	0
24	30,060	30,060	0	13,400	13,400	0
TOTALS	260,700	271,180	10,480	(4.0)	99,700	4,550(4.7)

* These sites had a positive coefficient on the travel cost variable.

Table 4-5

Valuation of Resource Losses Due to Acidification: Moderate Acreage and Catch Rate Loss Scenario

($ x 10^3 per year, 1984 dollars)

Site	Current Willingess To Pay	Willingness to Pay Given No Acidification	Losses	Current Consumer Surplus	Consumer Surplus Given No Acidification	Losses
1	10,330	10,330	0	3,030	3,030	0
2	11,400	13,410	2010	2,910	3,540	630
3	5,420	7,740	2320	1,270	2,080	810
4	4,720	5,210	490	1,490	1,870	380
5	8,380	8,390	10	2,510	2,520	10
6	10,620	11,740	1120	4,040	4,510	470
7	12,160	12,200	40	4,370	4,390	20
8	19,950	20,230	280	6,330	6,430	100
9	8,610	8,640	30	2,930	2,940	10
10	(*)	(*)	(*)	(*)	(*)	(*)
11	3,560	3,970	410	1,150	1,290	140
12	10,270	10,270	0	3,700	3,700	0
13	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
14	10,610	22,430	710	3,050	3,230	180
15	6,540	6,620	80	2,120	2,150	30
16	4,690	4,720	30	2,080	2,090	10
17	7,830	7,870	40	2,180	2,190	10
18	11,250	11,310	60	3,780	3,810	30
19	28,870	28,870	0	10,280	10,280	0
20	(*)	(*)	(*)	(*)	(*)	(*)
21	12,860	12,930	70	3,980	4,000	20
22	6,740	9,530	2,790	3,050	4,630	1,580
23	35,890	35,890	0	17,460	17,460	0
24	30,060	30,060	0	13,400	13,400	0
TOTALS	260,700	271,180	10,480	100,010	4,860	

* These sites had a positive coefficient on the travel cost variable.

Table 4-6

Valuation of Resource Losses Due to Acidification: High Acreage and Catch Rate Loss Scenario

($\$ \times 10^3$ per year, 1984 dollars)

Site	Current Willingess To Pay	Willingness to Pay Given No Acidification	Losses	Current Consumer Surplus	Consumer Surplus Given No Acidification	Losses
1	10,330	10,330	0	3,030	3,030	0
2	11,400	15,770	4,370	2,910	4,320	1,410
3	5,420	8,140	2,720	1,270	2,280	1,010
4	4,720	7,760	3,040	1,490	3,200	1,710
5	8,380	8,380	10	2,510	2,510	0
6	10,620	12,910	2,290	4,040	5,060	1,020
7	12,160	13,520	1,359	4,370	4,920	550
8	19,950	22,860	2,910	6,330	7,400	1,070
9	8,610	8,690	80	2,930	2,940	10
10	(*)	(*)	(*)	(*)	(*)	(*)
11	3,560	4,400	840	1,150	1,470	320
12	10,270	13,280	3010	3,700	5,000	1,300
13	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
14	10,610	11,320	710	3,050	3,230	180
15	6,540	6,620	80	2,120	2,150	30
16	4,690	5,050	360	2,080	2,250	170
17	7,830	8,070	240	2,180	2,250	70
18	11,250	11,440	190	3,780	3,850	70
19	28,870	28,870	0	10,280	10,280	0
20	(*)	(*)	(*)	(*)	(*)	(*)
21	12,860	13,550	690	3,980	4,210	230
22	6,740	10,780	4,040	3,050	5,510	2,460
23	35,890	35,890	0	17,460	17,460	0
24	30,060	30,060	0	13,400	13,400	0
TOTALS	260,700	287,900	27,200	95,150	107,190	12,040

* These sites had a positive coefficient on the travel cost variable.

4) Using the moderate acreage loss estimate and assuming that the catch rate declines proportionately, the estimated decline in the resource value is 11.8 million dollars per year and the loss of consumer surplus is 4.9 million dollars.

5) Using the high acreage loss estimate and assuming a proportionate change in catch rate, the estimated decline in the resource value is 27.2 million dollars and the loss in consumer surplus is 12.0 million dollars.

There are a number of factors that must be considered when interpreting these results. First, the correct measure of benefits for use in a benefit-cost analysis of acid deposition is the change in consumer surplus. Second, the data set used in the analysis only includes information on visits to lakes. Streams in the Adirondacks were not examined due to the lack of data on the characteristics of the streams and uncertainty in the actual fishing location. Data in the Anglers Survey indicated that approximately one third of fishing trips listed a stream as the final destination.

Third, sites 10, 13 and 20 were not assigned a value. Site 13 was not valued due to an error in the computer program that combined the data in the Anglers Survey and the Ponded Waters Survey. There were not adequate resources available to go back and correct this error. Sites 10 and 20 had the wrong sign on the coefficients on the travel cost variables. As a result, willingness-to-pay estimates for these sites were not available from the statistical analysis. These sites certainly have some value. An examination of the data presented in Table 4-2 shows each of these sites is susceptible to acidification with the high estimates of fishable acreage losses being 16.7 percent, 21.3 percent, and 27.7 percent respectively. Thus, the exclusion of these sites in the value estimates contained in this draft report biases the estimated effects of acidification downward.

Fourth, the travel cost model in its present version does not explicitly take into account the substitutability of fishing sites. This will tend to result in estimates of losses that are overstated. See Section 4.3 for a more complete discussion of this point.

Fifth, the travel cost analysis considered only trips that have a one-way distance of 225 miles or less. This was done to avoid including multi-purpose trips where fishing may not have been the primary reason for the trip. The inclusion of these trips would have biased the estimates and made the results uninterpretable. Still, these trips represent fishing days spent at the site which have value. In scaling the sample estimates up to a population estimate, it was assumed that fishing days from trips of distances greater than 225 miles resulted in the same consumer surplus as shorter trips. The actual consumer surplus resulting from fishing days taken as part of a multi-purpose trip could be either greater or smaller than that estimated from the shorter trips. Still, over 70 percent of the fishing days were from trips of less than 225 miles.

4.2 ESTIMATING THE DAMAGES FROM ACIDIFICATION USING THE PARTICIPATION MODEL

As a final piece of analysis, the participation model developed in Section 4.1 can be used in conjunction with the resource value estimates from Table 4-1 to estimate the damages from acidification. The participation model found a robust relationship between the number of fishing days spent at a site and fishing opportunities measured by fishable acreage and fishing success measured by the total catch rate. Equation 3 from Table 3-1 presents the estimated relationship between fishing days and a site's fishable acreage and catch rate:

$$\text{Fishing Days} = \underset{(5.66)}{.0978}\,(\text{Net Park Acres}) + \underset{(1.97)}{199.4}\,(\text{Catch Rate}) + \text{intercept}$$

The R-square for this equation was .615. The moderate loss due to acidification scenario from Table 4-2 resulted in an average reduction in fishable acreage of 3.2 percent and the high loss scenario resulted in an average acreage reduction of 10 percent. The mean values across all sites for net park acres and catch are 7420 and 3.47 respectively. Using these mean values to represent the average site, the effect of acidification on total fishing days for this average site can be calculated. Then, the average willingness to pay ($85) and consumer surplus ($31) per fishing day from the travel cost model (see Table 4-1) can be used to calculate an estimate of damages. Four scenarios are evaluated.

Scenario 1 - Assuming moderate acreage losses and no change in catch rate, a reduction of 56,000 fishing days across all site - is estimated. Losses in terms of willingness to pay and consumer surplus is 4.8 and 1.7 million dollars per year respectively.

Scenario 2 -- Assuming high acreage losses and no change in catch rate, a reduction of 173,000 fishing days across all sites is estimated. Losses in terms of willingness to pay and consumer surplus is 14.7 and 5.4 million dollars per year respectively.

Scenario 3 -- Assuming moderate acreage losses and a proportionate change in catch rate, a reduction of 109,000 fishing days is estimated. Losses in terms of willingness to pay and consumer surplus is 9.3 and 3.4 million dollars per year respectively.

Scenario 4 -- Assuming high acreage losses and a proportionate change in catch rate, a reduction of 340,000 fishing days across all sites is estimated. Losses in terms of willingness to pay and consumer surplus is 28.9 and 10.5 million dollars per year respectively.

4.3 COMPARISON OF PARTICIPATION MODEL AND TRAVEL COST MODEL ESTIMATES OF DAMAGES

The damage estimates derived in terms of reduced consumer surplus from both the travel cost model and participation model are presented in Table 4-7. The estimates derived from the two models are quite similar in magnitude. There is no clear reason to prefer one set of estimates over the other. The use of average values in the participation model poses some problems, but are reasonable approximations for the modest changes in site characteristics examined in this study. One favorable attribute of the participation model results was the robust statistical relationship that was found between fishing days and site attributes. The statistical relationship found in the second stage of the varying coefficient travel cost model was less robust.

Table 4-7

Estimates of Damages Resulting from Acidification

($ x 10^6 per year; in 1984 dollars)

Assumed Acidification Scenario	Estimated Consumer Surplus Losses from the Travel Cost Model	Estimated Consumer Surplus Losses from the Participation Model
1. Moderate acreage losses and no change in catch rate	.7	1.7
2. High acreage losses and no change in catch rate	4.6	5.4
3. Moderate acreage losses and proportionate changes in catch rate	4.9	3.4
4. High acreage losses and proportionate changes in catch rate	12.0	10.5

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DRAFT

Modeling Recreational Demand in a Multiple Site Framework

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Introduction

There is a large and growing literature on recreational demand modelling. A topic which has, of late, received particular attention in this literature is the modelling of the demand for systems of alternative sites, as compared with the more traditional single site modelling approaches. The multiple site models are frequently complex, diverging from simple intuitive extensions of the single site model, They are also diverse, and this together with their complexity makes assessment and comparison of models and results difficult. While problems in the theory and application of single site models remain, most practitioners understand these models and their inherent problems and can apply them with a cautious confidence. In contrast, multiple site models are difficult to sort out, to interpret and to estimate.

In this paper, we first explore the reasons why multiple site models have been developed and outline a number of the approaches which have been used. We then assess these models with a specific criteria in mind: how well do they account for the specific nature of benefit changes in a multiple site framework? Using a common data set, we demonstrate a few of the estimation techniques.

Why Multiple Site Modelling?

A Review of Approaches with Trip Allocation and Site Valuation Motivations

The long list of models which treat multiple sites can be subdivided into three categories: (a) those which are used primarily to explain the allocation of visits among alternative sites; (b) those which may explain allocation, but also value the addition of a new site; and (c) those which focus on the valuation of site characteristics. The models in (a) and (b) often include site characteristics as explanatory variables but do not always facilitate the valuation of characteristics. Some, but not all, of those in (c) also explain trip allocation decisions.

One of the first treatments of multiple sites was in the context of zonal trip allocation models. In 1969 Cesario suggested the use of these gravity models for the specific purpose of explaining the allocation of trips from each zone to alternative sites. In these models visits between a zone and a site were explained on the basis of zonal and site characteristics and distance, with one set of parameters estimated for all combinations of zones and origins. For the most part such models have been used Simply to estimate demand and predict use rates. Freund and Wilson (1974) provided one of the most careful applications of this approach in a study of recreation travel and participation in Texas.

In their 1975 paper Cesario and Knetsch extended the gravity model so that the trips equation for zone i visitors to site j included a factor reflecting "competing opportunities" provided by all other sites. presumably this made more explicit the substitutability among sites. These authors also introduced the possibility of using gravity models for benefit measurement. Including travel cost (time and money costs) instead of distance, Cesario and Knetsch proceeded to treat the zonal visits equations as demand curves and take areas behind these curves as measures of consumer surplus.

The use of gravity models for benefit estimation has been limited, culminating in a rather complex paper by Sutherland published in 1982. Unlike his predecessors, Sutherland obtained predictions of individual's behavior rather than simply zonal aggregates. The model had four components which, while inextricably linked, were estimated independently. Each zone's demand for trips to all sites (trip production models), $T_{i\bullet}$, and each site's aggregate demand from all zones (attractiveness models), $T_{\bullet j}$, were estimated. predicted values for these variables were combined with variables reflecting distances in a trip distribution (gravity) model to predict each zone's allocation of visits among all sites, T_{ij}. It seems that results from this gravity model were then used to estimate a demand function where predicted trips by zone to each origin was regressed on travel cost (constructed from the distance data). The model, at best, seemed to overfit the demand system.

Sutherland's paper inadvertently exposed what is perhaps the most disturbing aspect of the gravity models. They are simply statistical allocation models based on no particular arguments about economic behavior. Consequently, when Sutherland used a gravity model to "allocate trips from zones to sites," he did not have a model of the requisite economic behavior to estimate benefits. He then was forced to re-estimate a relationship between trips and cost to capture the economic behavior implicit in a demand function. It is difficult to understand why one would wish to estimate a gravity model for benefit estimation purposes a) if one does not believe the gravity model is a demand function and b) if one believes that decisions are driven by economic considerations.

Burt and Brewer (1971) were perhaps the first explicitly to specify multiple-site demand models. Their motivation for going beyond the single-site model was that they were interested in measuring the value of introducing a new recreational site. For such a potential value to be measurable, one needs to admit the existence of at least one other similar site. Once the existence of at least one alternative site is recognized, it seems appropriate to estimate the system of demands for all existing alternatives. Thus in deducing the value of the new site, Burt and Brewer set off to estimate how patterns of demand for existing sites would change with its addition.

The Burt and Brewer model was a straightforward extension of the single site travel cost model to a system of such demands

(1) $$q_k = f_k(p_1, p_2, \ldots, p_m, y) \qquad k = 1, \ldots, m$$

where q_k is the number of trips taken to site k, p_k is the travel cost to site k, y is income and m is the number of sites in the system considered. Any differences due to the quality characteristics of sites simply showed up in the estimated coefficients of the different demand functions. Unlike so many studies of this time, the authors used household rather than zonal data in their application - a study of water based recreation in Missouri.

A similar model (with the omission of income and based on zonal data) was employed by Cicchetti, Fisher, and Smith (1976) in their analysis of the Mineral King project in California. Once again the motivation was the valuation of a proposed new site. Similar to Burt and Brewer, the authors estimated a system of demands for alternative sites or site groups as functions of prices (i.e. the costs of traveling to each site). And, again, site characteristics were excluded from the model.

In each case the benefits from the introduction of the new site were assessed by considering the benefits of a price change for the existing site most similar to the proposed site. Thus, gains from the new site accrued from reduced travel costs for some users.

Hof and King (1982) asked the very pertinent question - Why do we need to estimate the system of demands in these cases? Why not just estimate the demand for the similar site (as a function of all prices) and evaluate the benefits in that market? In the context of the Burt and Brewer and the Cicchetti, Fisher and Smith papers, their arguements are cogent. If there is only one price change, its effect can be measured in one market (Just, Hueth, and Schmitz, 1982). Even if one expects seemingly unrelated regression problems, ordinary least squares will achieve the same results as generalized least squares when all equations include the same variables.

Hof and King further argued that Willig's results provide bounds on compensating variation as functions of Marshallian consumer surplus. Thus, it is not necessary to estimate the entire demand system so as to impose cross-price symmetry and ensure path independence. In retrospect, this procedure of imposing symmetry (followed by both the Burt and Brewer and the Cicchetti, Fisher and Smith papers) seems inappropriate, since there is no reason for the Marshallian demands to exhibit such characteristics. Additionally this path independence property is not worth worrying about since the particular functional forms chosen for the systems of demand functions in these papers do not meet integrability conditions (LaFrance and Hanemann, 1984). In any event, if we are interested in the effect of a single price change, there would seem no especially compelling reason to estimate an entire system of demands if they are to take the form suggested by Burt and Brewer or Cicchetti, Fisher and Smith.

All of the models mentioned so far included multiple sites to capture allocation of trips among substitute alternatives. Some of the gravity models attempted to Capture the effect of site characteristics on this allocation, but were not concerned with the valuation of characteristics. The demand systems models did not even attempt to take explicit account of site heterogeneity.

Of the more recent and more sophisticated modelling attempts, only one has this same type of motivation. While the multiple site models of Morey (1981, 1984a, 1984b) are more closely aligned in technique and conception to the models outlined in the next section, their motivation is more akin to the earlier models discussed above. They have been employed by the author both to explain the allocation of visits among alternative sites (1981, I984a) and to value the introduction of a new site (1984b). The approach nonetheless places heavy emphasis on site characteristics, with characteristics contributing to the explanation of trip allocations, and there is no reason why the approach could not be used to value characteristics. Because of this, we will postpone discussion of this work until the next section.

Multiple Site Modelling and the Valuation of Site Characteristics

Of burgeoning interest in environmental economics is the valuation of improvements in environmental quality. While valuation exercises have frequently taken place in the context of contingent valuation models, economists have concurrently tried to adapt recreational demand models to this task. This has given a new and more insistent motivation for multiple site modelling. It was quickly realized that in order to value characteristics one needed to estimate demand as a function of characteristics and this required observing variation in characteristics over observations. This variation could, presumably, be found only by looking across recreational sites.

In what follows we will be describing approaches which are currently being used to model multiple site demand and which can be used to value environmental improvements. The first approach we shall outline here has as its sole focus the valuation of site characteristics. The hedonic travel cost model (Brown and Mendelsohn, 1984; Mendelsohn, 1984) attempts to reveal shadow values for characteristics by estimating individuals' demand for the characteristics. This approach consists of two separate procedures. The first step entails regressing individuals' total costs of visiting a site on the characteristics of the site. Each individual is assumed to visit only one site and separate regressions are run for individuals from each origin. The costs of visiting any given site and characteristics of the site are identical for all individuals visiting the site from the same origin, and variation in the data comes from variation in the sites visited by those individuals from the same origin. The partial derivatives of cost with respect to characteristics are then interpretted as the hedonic prices of the characteristics. The hedonic prices are used as prices in a second stage where the demand for characteristics is estimated.

Since chance and not markets provides the array of sites and their qualities, it is unreasonable to expect costs of accessing <u>all</u> possible sites for all individuals to be an increasing function of even one characteristic. However the approach requires including observations on costs and site characteristics only for those sites which are actually visited by individuals in the regression subsample. It is, of course, a logical result of constrained utility maximization that an individual will only incur greater costs to visit a more distant site if the benefits derived from the visit exceed those from a closer site. Nonetheless, it does not seem to follow that costs will be a single-valued, increasing function of each element of a vector of site characteristics.

The conceptual validity of the hedonic travel cost approach depends on two contentions which remain contestable and unproven. No attempt will be made to resolve these particular issues here, as we are interested in other dimensions of the multiple site modelling problem. However, we mention the problems in hopes of stimulating discussion. The first contention worthy of debate is whether the derivatives of the first stage regression legitimately reflect prices - the prices an individual perceives himself to have to pay to increase the level of the characteristics. If more than one characteristic is included in the function, or if important characteristics are omitted - and especially if sites are not continuous, it becomes quite possible for costs to be declining in at least one characteristic, thus producing a negative "hedonic price."

Presuming for a moment that orderly prices for individual characteristics exist, the second debatable contention is that true demand functions for the characteristics can be statistically identified. This identification issue has been debated extensively in the context of the hedonic property value technique for valuing amenities, but many of the same points of controversy arise here. For a sampling of the arguments, see Brown and Rosen (1982), Mendelsohn (1983), and McConnell (1984).

The output of the final stage of the hedonic travel cost approach is a demand function for each characteristic. The demand function, although not derived from a utility maximizing framework, is interpretted to reflect the marginal willingness to pay per recreation day for an increase in the quality of the characteristic. There is an apparent inconsistency in the interpretation as we consider hpothetical movements away from the observed point. The demand functions are associated with characteristics and not sites and thus it does not seem possible to assess the value of a specific change in quality (such as would be brought about by a regulation, etc.) Also these functions do not capture any information about how individuals' behavior (participation and site choice) would change with a change in quality. Without this latter information, it would not seem possible to assess the value of a change.

A second approach which is both interesting and potentially fruitful is due to Morey. This approach models shares of total recreational trips allocated to alternative sites. Several techniques for statistically estimating shares which are consistent with demand functions have been proffered by economists (see for example Woodland, 1979, and Hanemann's cataloguing in Bockstael, Hanemann and Strand, 1984). Morey chooses a share model based on the multinomial distribution which has the appealing features that if the shares are assumed to follow such a distribution, then the implied demands are "counts" and therefore non-negative integers.

The standard scenario underlying the multinomial distribution is that R independent trials are held and, on each trial, N mutually exclusive outcomes may occur, with π_i being the probability of the i^{th} outcome where $\pi_i > 0$ and $\sum_{i=1}^{N} \pi_i = 1$. Let t_i be the number of times that the i^{th} outcome occurs in R trials. The probability of an outcome vector $(x_1,\ldots,x_N)$ is

$$(2) \qquad f(t_1,\ldots,t_N) = \frac{R!}{\prod_{j=1}^{N} t_j!} \prod_{j=1}^{N} \pi_j^{t_j}.$$

Applications of the multinominal distribution (such as Morey's) equate the count t_i with the number of trips to site i, x_i, and π_i with the share function $s_i(p,b,y_X)$. The total number of trials, R, is equivalent to the total number of trips, X. The density of the observed demands is then

$$(3) \qquad f(x_1,\ldots,x_N) = \frac{(x.)!}{\prod_{j=1}^{N} x_j!} \prod_{j=1}^{N} s_j(p,b,y_x)^{x_j}.$$

parameters of the $s_j(\cdot)$ are then estimated by maximizing the likelihood function

(4) $$L = \prod_{m=1}^{M} \frac{(x_.)!}{\prod_{j=1}^{N} x_j!} \prod_{j=1}^{N} s_j(p, b, y_x)^{x_j}$$

where M is the number of individuals in the sample.

The logic of the statistical model is that the number of trials, R, is exogenous. and, therefore, this parameter may be ignored in maximizing the likelihood function to obtain estimates of the π's. However, R equals x., the total number of trips, and thus contains information on the coefficients to be estimated which should not be ignored in estimating the likelihood function. Additionally, the approach provides estimates of shares and not demands. The prediction of demands would require the prediction of total number of visits as well. Interesting, the shares are consistent with a system of demand functions which could be estimated to obtain information on total trips as well as their allocation.

An alternative approach is to retain the multinomial model but interpret the parameters, $\pi_1,\ldots,\pi_N$, not as shares per se, but as choice probabilities arising from some structural economic model. Variations of this appraoch can be found in Caulkins (1982), Hanemann (1978), Feenberg and Mills (1980), and Bockstael, Hanemann, and Strand (1984).

Recalling the expression for the multinomial distribution in (2) a different interpretation is now employed. Rather than treat the allocation of total demand, we are now concerned with the decision of what site to visit on each choice occasion. Thus π_j becomes the probability that alternative j is chosen on the given choice occasion and t_j equals 1 if j was chosen, 0 otherwise. In this way of structuring the problem, the expression $R!/\prod_{j=1}^{N} t_j!$ disappears, since the number of repeated trials is 1. Finally, the likelihood function takes the form

(5) $$L = \prod_{m=1}^{M} \prod_{g=1}^{G} \prod_{j=1}^{N} \pi_{jgm}^{t_{jgm}}$$

where m indexes individuals, j indexes alternatives , and g indexes individuals' choice occasions. In this formulation π_i is still constrained to be strictly positive but this does not preclude si equaling zero since π is no longer a share but instead the probability of choosing alternative i on a given choice occasion.

The probabilities, π_{jgm}, are determined by costs and characteristics of the alternatives and the characteristics of the individuals in a utility maximizing framework. On each choice occasion, the individual chooses one alternative site to visit. In order to describe the solution, suppose that on the given choice occasion, the individual has selected site i. Since the consumer selects the site which yields the highest utility, the decision can be expressed in terms of conditional indirect utility functions as

$$(6) \qquad d_i = \begin{cases} 1 & \text{if } v_i(b_i, y_r - p_i) > v_j(b_j, y_r - p_j) \quad \text{all } j \\ 0 & \text{otherwise} \end{cases}$$

where d_i is a choice index which equals 1 when the i^{th} site is chosen, and v_i is the indirect utility function conditioned on the choice of visiting site i. Notice that we have involved a weak complementarity assumption here by including only b_i, the vector of quality characteristics associated with site i in the function. Here y_r is the income available per choice occasion.

For estimation purposes, it is necessary to introduce a stochastic element into this demand model. If we assume that the random elements enter the utility functions in such a way that they, too, are affected by weak complementary, then we can write each conditional indirect utility function, $v_i(\cdot)$ simply as a function of a scalar random element, ε_i. The consumer's utility maximizing choice is still expressed in terms of the conditional indirect utility functions, along the lines of (5), except that the discrete choice indices $d_1,\ldots d_N$ are now random variables with means $E[d_i] =$ π_i given by

(7) $$\pi_i = Pr\left\{v_i(b_i, y_r - p_i; \varepsilon_i) > v_j(b_j, y_r - p_j; \varepsilon_j) \quad \text{for all } j\right\}.$$

To estimate the parameters of these indirect utility functions, one needs to assume a tractable distribution for the ε's. At this point the various discrete choice multiple site models diverge. A common assumption e.g. (Caulkins, Feenberg and Mills, Hanemann) is that the random variables, $\varepsilon_1, \ldots, \varepsilon_N$ are independently and identically distributed extreme value variates, and that they are additive in the indirect utility function, i.e.

$$u_i = v_i(b_i, y_r - p_i) + \varepsilon_i \qquad i = 1, \ldots, N.$$

This yields the logit model of discrete choices

(8) $$\pi_i = e^{v_i} / \sum_{j=1}^{N} e^{v_j} \qquad i = 1, \ldots, N.$$

In Bockstael, Hanemann, and Strand, the Generalized Extreme Value Distribution (of McFadden, 1978) is employed such that

(9) $$P_r\left\{\varepsilon_i \leq s_1, \ldots, \varepsilon_N \leq s_N\right\} = \exp[-G(e^{-s_1}, \ldots, e^{-s_N})]$$

where G is a positive, linear homogeneous function of N variables. When combined with the indirect utility function with additive errors, this yields discrete choice probabilities of the form

(10) $$\pi_i = e^{v_i} G_i(e^{v_1}, \ldots, e^{v_N}) / G(e^{v_1}, \ldots, e^{v_N}) \quad i = 1, \ldots, N$$

where $G_i(\cdot)$ is the partial derivative of $G(\cdot)$ with respect to its i^{th} argument. In either case, the formulas for the choice probabilities may be substituted into the multinomial density for maximum likelihood estimation of the parameters in the $v_i(\cdot)$ functions.

The treatment of choice occasions is also different in the various models. Caulkins considers each choice occasion to be each day of the year and Feenberg and Mills each day of the recreational season, but both presume that on each day, the individual decides both whether to participate in the recreational activity and, if he participates, which site he visits.

To accomplish this, Caulkins first estimates a logit model on the site choice decision:

(11) $$\pi_i = e^{v_i} / \sum_{j=1}^{N} e^{v_j}$$

and then defines an index which, although not completely consistent, is conceptually similar to the inclusive value index of McFadden. This index, $\tilde{I}$, is a linear function of the average price and quality characteristics of the alternative sites. The probability of participation is estimated as the following binary logit

(12) $$\pi_p = e^{\tilde{I}}/e^{v_0} + e^{\tilde{I}}$$

where v_0 is the utility associated with not participating and is a function of income (and potentially other characteristics of the individual).

Feenberg and Mills estimate the same type of first stage logit model in analyzing site choices. Their model employs a similar inclusive value index

(13) $$I = \ln \sum_{j=1}^{N} e^{v_j}.$$

The participation decision is once again a function of the inclusive value index and v_0, but it is estimated using ordinary regression techniques.

The above studies have one characteristic in common: the total number of trips taken in a season is determined indirectly by adding up the number of independent occasions upon which the individual chooses to participate in recreation. Treating the total consumption decision as the sum of totally uncoordinated micro decisions is not especially appealing. Bockstael, Hanemann and Strand offer an alternative approach which on some grounds may be considered slightly more appealing but which still fails to be rigorously derivable from a single utility maximizing framework. The essence of this approach is that a logit model (in this case a slightly more complex, generalized extreme value model) is estimated on site choices per choice occasion. But rather than considering every day of the year (or season) to be an independent choice occasion upon which the individual must decide whether to participate, the participation decision (both whether to be a participant in this activity at all and, if so, how much) is estimated as one discrete-continuous total recreation demand decision. This macro decision of how many days in the season to recreate is estimated using a discrete-continuous choice model which takes account of the fact that decisions will be nonnegative but may be zero for a number of people. Although of a different form from the other models, the decision is estimated as a function of similar variables: the characteristics of the individuals and the characteristics of the recreational opportunities available as captured through an inclusive value index. The specific model used is presented in the estimation section of this paper.

A comparison of this approach with the Feenberg and Mills and Caulkins models exposes an important difference. In this model the probability that an individual is not a recreationalist, i.e. he does not participate at all in the recreational activity, is estimated directly. Either Tobit or Heckman procedures can be used to estimate this equation. The later procedure is particularly appropriate if factors such as old age, ill health or preferences for other activites causes an individual never to recreate. In the other approaches where total visits are determined by the summation of independent decisions on sequential choice occasions, nonparticipants happen, in a sense, by accident. They are predicted to be those individuals who happen to have a string of zero predicted responses to a sequence of N independent micro decisions. Modelling the macro allocation separately would appear to be a more realistic and useful description of individual behavior. However, it does not offer a consistent way to link independent site choice decisions and the demand for total trips with a common underlying utility maximization framework.

Welfare Measurement Given The Nature of Recreational Decisions

One can certainly argue with features of all of the models outlined above. Here we will be concerned with only one criteria, albeit an extremely important one, for assessing alternative models. The criteria is how adequately each model captures the appropriate benefits which accrue from an environmental change, given the nature of recreational decisions in a multiple site framework.

It is important at this point to reiterate and to develop more fully what we mean by the nature of recreational decisions. Suppose we are interested in valuing an improvement in water quality, and we attempt to do this by looking at recreational behavior over an array of recreational sites with different water quality in the region of interest. Any sample of the relevant population will turn up a fair number of individuals who do not participate in water recreation at these sites at all. Of those who do participate in the activity, it will be unusual to find anyone who visits all sites. It will also be unusual if the entire data set consists of individuals each of whom visit only one site. Additionally, we are interested in how many trips an individual takes to each site. Thus we observe either that an individual did not participate in the activity at all or that he participated but took no trips to several sites and a positive number of trips to some subset of sites.

Recreational behavior is complicated to model because of this mix of continuous and discrete decisions and because decisions result invariably in corner solutions. Nonparticipants are, of course, at a corner solution with respect to the total trips decision. participants are even observed to be at corner solutions of a sort since they take zero trips to at least some sites. One of the drawbacks of the straight-forward demand systems modelling of Burt and Brewer and Cicchetti, Fisher and Smith is that they are predicated on the assumption of interior solutions to the utility maximization process. Once we admit to corner solutions, the nature of demand systems changes.

This criticism is in some ways applicable to the share models as well. The share models treat the total number of trips as fixed. Additionally most of these models implicitly presume a nonzero share (however small) for all sites. The share models can be transformed into demand systems and estimated in that form, providing predictions of total number of trips. However such models suffer from the same problem as the Burt and Brewer type models in that they presume interior solutions. Many of the discrete choice approaches get around the problem by estimating decisions per choice occasion. This ignores interdependence across trip decisions and provides estimates of total trips demanded only in an indirect and unsatisfactory way. The final discrete choice model suggested above attempts to mitigate the second of these criticisms, but does so in a way which is not completely consistent with a utility maximization framework.

Given the complexities of the decision making process, a pertinent question at this point is: How important is it to model behavior, if we are interested simply in valuing changes in characteristics (e.g. environmental improvements)? The answer to this question is critical. The costs of obtaining good models of behavior in this context are high and we need to know whether they are worth it,

One can debate the importance of wholly consistent, utilitic theoretic models, but what is much more certain is the importance of estimating effectively the complex dimensions of recreational demand. There are two reasons for this. Estimation can be biased if account is not taken of corner solutions (see for example the literature on truncated and censored samples). More important for our purposes here, welfare measurement in this context depends on the behavioral adjustments of individuals. In the next section, we will summarize some of the work on welfare measurement in a discrete choice framework but this must await a more rigorous description of the recreationalists' decision model. At this point, it is useful to present some intuition.

Consider once again the water quality example. Suppose there are N sites and water quality is improved at one of these sites, j. It is true that those who visit site j will benefit, How much they benefit will be affected by how many trips they take to site j - a decision which might change with the improvement of the site. Additionally, recreationalists who did not previously visit site j may now find it desirable and may move from corner solutions for visits to site j to positive demands. Finally, we may find the improvement of site j attracting previous non-participants into the recreational activity.

Now suppose more than one site's quality is improved, a more likely result of a regional implementation of an environmental regulation. Then, depending on the pattern of improvements, all sorts of re-orderings may take place. Some sites may be improved but may generate no user net benefits because they actually lose visits to other <u>more</u> improved sites. Clearly the welfare gains to an individual at any one site are conditioned on his decision to visit that site and must be adjusted by the probability of that site being visited. Models which do not take into account changes in behavior can not accurately measure benefits.

Corner Solution Models and Welfare Evaluation

In this section we present an approach which takes account conceptually of all aspects af the multiple site recreational decision. The "general" corner solution model is extremely difficult to estimate, but we present its logic here for two reasons. The approach incorporates in a consistent way all facets of the recreational decision process and thus provides a standard by which to compare other, more tractable, approaches. Also it facilitates a clear statement of appropriate welfare measures.

We make a distinction here between "extreme" and "general" corner solution models. "Extreme" corner solutions arise when something in the structure of the decision forces a corner solution in all but one of the site demands (which we shall denote x_i). This can occur either because the sites are perfect substitutes or because for some logical or institutional reason, the sites are mutually exclusive. By contrast, a "general" corner solution arises when some, but no necessarily N-1, of the x_i's are zero at the optimum.

For most recreation choices one finds evidence of a general rather than an extreme corner solution. The total demand for the class of commodities is allocated to more than one, but less than N, of the quality differentiated goods. However, the analysis of extreme corner solutions is more straightforward and will set the stage for the more general models.

Suppose for the moment, that the consumer has decided to consume only good i (visit site i). His utility, conditional on this decision, can be written as

(14) $$u_i = u(0,\ldots,0,x_i,0,\ldots,0,b,z;\varepsilon)$$

where x_i is the number of visits to site i, b is of vector of site characteristics, z is a Hicksian good and ε is a random vector. The conditional direct utility function can be written (if we assume weak complementarity between site characteristics and visits) as

(15) $$u_i^*(x_i,b_i,z;\varepsilon_i).$$

Given his selection of this site, he still must make a decision as to the number of times he should visit it over the recreation season by solving:

(16) $$\underset{x_i\ z}{\text{maximize}}\ u_i^*(x_i,b_i z;\varepsilon) \quad \text{s.t.} \quad \begin{array}{l} p_i x_i + z = y \\ x_i \geq 0,\ z \geq 0. \end{array}$$

The solutions are

(17)
$$x_i = h_i^*(p,b,y;\varepsilon)$$
$$z = z_i(p_i,b_i,y;\varepsilon) = y - p_i h_i^*(p_i,b_i,y;\varepsilon).$$

These demand functions are "conditional" ordinary demand functions, conditional on an interior solution for x_i (i.e. conditional on the decision to consume the particular x_i at a nonzero level and all other x's at a zero level). The conditional indirect utility function obtained by substituting these functions back into $u_i^*(\cdot)$ is $v_i^*(p_i,b_i,y;\varepsilon)$. These functions are random variables from the point of view of the econometric investigator, and their distribution may be derived from the assumed joint density of $\varepsilon, f_\varepsilon(\varepsilon)$.

All of the foregoing is conditional on the consumer's selecting site i. The discrete choice of which site to select can once again be represented by a set of binary valued indices $d_1,\ldots,d_N$ where $d_i = 1$ if $x_i > 0$ and $d_i = 0$ if $x_i = 0$. The choice may be expressed in terms of the conditional indirect utility functions as

(18)
$$d_i(p,b,y;\ ) = \begin{cases} 1 & \text{if } vi^*(p_i,b_i,y;\varepsilon) \geq v_j^*(p_j,b_j,y;\varepsilon), \quad \text{all } j \\ 0 & \text{otherwise} \end{cases}$$

where the expected value of d_i is

(19)
$$\pi_i(p,b,y;\varepsilon) = \Pr\left\{v_i^*(p_,b_i,y;\varepsilon) \geq v_j^*(p_j,b_j,y;\varepsilon), \quad \text{all } j\right\}.$$

The "unconditional" demand functions can not be derived by applying the standard calculus but are defined by the conditional ones together with the binary valued indices:

(20)
$$h^i(p,b,y;\varepsilon) = d_i(p,b,y;\varepsilon)h_i^*(p_i,b_i,y;\varepsilon) \qquad i = 1,\ldots,N$$

Additionally, the unconditional indirect utility function is given by

(21) $$v(p,b,y;\varepsilon) = \max[v_1^*(p_1,b_1,y;\varepsilon),\ldots,v_N^*(p_N,b_N,y;\varepsilon)].$$

The practical application of extreme corner solution models rests on the ability to devise specific functional forms for the conditional indirect utility functions and the joint density $f_\varepsilon(\varepsilon)$ which yield reasonably tractable formulas for the discrete choice probabilities and the conditional demand functions. Hanemann (1984a) presents a variety of demand functions suitable for extreme corner solutions which offer considerable flexibility in modelling price, income, and quality elasticities.

Unfortunately, it is "general" and not "extreme" corner solutions which characterize most multiple site recreational decisions, and the general corner solution is more difficult to estimate. Several approaches to treating this problem are explored by Hanemann in Bockstael, Hanemann and Strand (Chap. 9). However, in this paper we consider only one for exposition.

The generalized corner solution differs from the extreme corner solution in that more than one alternative (site) is chosen and has a nonzero level of demand. One estimation procedure appeals to the economic considerations underlying the solution to the utility maximization problem embodied in the Kuhn Tucker conditions. Substituting the budget constraint into the utility function, this problem may be written

(22) $$\text{maximize } u(x,b,z;\varepsilon) =$$
$$\text{maximize } u(x,b,y_r - \textstyle\sum p_j \bar{x}_j;\varepsilon) \qquad \text{s.t. } 0 \leq x_i \leq y/p_i \quad i = 1,\ldots,N$$

and the Kuhn Tucker conditions are

(23) $$x_i \begin{cases} = 0 \\ > 0 \end{cases} \quad \text{as} \quad \frac{\partial u}{\partial x_i} - p_i \frac{\partial u}{\partial z} \begin{cases} \leq 0 \\ = 0 \end{cases}$$

Suppose one observes an individual who purchases quantities $x_1,\ldots,x_Q$ of goods 1 _ and $y - \Sigma p_j\bar{x}_j$ of the Hicksian composite commodity, but nothing of goods Q+1,...,N. Define the N random variables $\eta_1,\ldots,\eta_N$ by

$$\text{(24)} \quad \begin{aligned} \eta_i &= \eta_i(x,p,b,y;\varepsilon) \\ &\equiv \frac{\partial u}{\partial x_i}(\bar{x},0,b,y-\sum_{j=1}^{Q} p_j\bar{x}_j;\varepsilon) - p_i\frac{\partial u}{\partial z}(\bar{x},0,b,y-\sum_{j=1}^{Q} p_j\bar{x}_j;\varepsilon) \end{aligned}$$

and let $f_\eta(\eta_1,\ldots,\eta_N)$ be their joint density derived from $f_\varepsilon(\varepsilon)$ by an appropriate change of variables. The probability of observing this consumption event is given by

$$\text{(25)} \quad \Pr\left\{\begin{array}{ll} x_i = \bar{x}_i, & i = 1,\ldots,Q \\ x_i = 0, & i = Q+1,\ldots,N \end{array}\right\}$$

$$= \Pr\left\{\begin{array}{ll} \eta_i = 0, & i = 1,\ldots,Q \\ \eta_i \leq 0, & i = Q+1,\ldots,N \end{array}\right\}$$

$$= \int_{-\infty}^{0}\cdots\int_{-\infty}^{0} f_\eta(0,\ldots,0,\eta_{Q+1},\ldots,\eta_N)\,d\eta_{Q+1},\ldots,d\eta_N.$$

Given the entire sample of consumers located at different corner solutions, the likelihood function would be the product of individual probability statements each having this form.

Two general points emerge from this analysis which are worth emphasizing. first, the probability expressions generally require the evaluation of an (N-Q)-dimensional cumulative distribution function - i.e. a multiple integral whose dimensionality corresponds to one less than the number of commodities not consumed. In the recreation case, where the number of sites (N) may equal perhaps 20, but the number of sites visited by an average individual (Q) will be 2 or 3, the evaluation of these integrals may be a daunting task unless one chooses the error structure and utility function carefully.

The second point worth emphasizing is that there is a basic tradeoff between achieving simplicity in the Kuhn-Tucker conditions and in the demand functions. In order to appreciate the significance of this tradeoff, it is necessary to consider the distinction between estimation and prediction as facets of the modelling activity. Both involve probability statements - estimation, for the purpose of forming likelihood functions; prediction, for the purpose of calculating the expected demand for sites under different price or quality regimes. In conventional demand analysis, including the share models described in the previous section, estimation and prediction are both based on essentially the same thing - the system of demand or share equations. Therefore, generally speaking, a stochastic specification which facilitates the process of estimation will also facilitate that of prediction, and conversely. This is not true when we deal with corner solutions, where estimation can be based on the (perhaps simple) Kuhn-Tucker conditions, while prediction is based on the (perhaps complex) demand functions. An alternative and promising line of attack would be to begin with the conditional indirect utility functions. This approach is outlined in Bockstael, Strand and Hanemann but not explored here.

At this juncture we proceed to discuss how, when estimated, the multiple site demand models can be used to derive money measures of the effect on an individual's welfare of a change in the qualities (or prices) of the available recreation sites. The task of performing welfare evaluations is more complex than the basic theory of welfare measurement (Maler 1971, 1974) when one works in a discrete choice, random utility setting. The theory of welfare measurement in this context has been developed by Hanemann (1982c), and revised and extended in Hanemann (1984c). We will provide a sketch of this theory here, leaving the reader to refer to these papers for a more detailed presentation. Both papers deal with extreme, rather than general, corner solutions but these can involve either purely discrete choices as in the logit models or mixed discrete continuous choices. After summarizing the methodology for these extreme corner solution models we will indicate how it can be extended to cover general corner solution models of the type discussed earlier. The compensation required by the individual to offset a change in prices and/or qualities from (p',b') to (p",b") are given by

$$v(p'',b'',y-C;\varepsilon) = v(p',b',y;\varepsilon). \tag{26}$$

(A similar expression exists for equivalent variation, which we shall ignore here to save space.) The problem in the random utility context is that C is now a random variable, since it depends implicitly on ε. How then, do we obtain a single number representing the compensating variation for the price/quality change?

Hanemann (1984c) presents three different approaches to welfare evaluations in the random utility context, only one of which we present here. That approach is based on the expectation of the individual's unconditional indirect utility function. In terms of this function, the measure of compensating variation is the quantity C' defined by

$$E[v(p'',b'',y-C')] = E[v(p',b',y)]. \tag{27}$$

This measure has been employed by Hanemann (1978, 1982c, 1983a), McFadden (1981), and Small and Rosen (1982). The formulas needed to calculate $E[v(\cdot)]$ for some common logit and probit additive-error random utility models are summarized in Hanemann (1982c). For example, in the GEV logit model

$$v(p,b,y) = \ln G(e^{v_1},\ldots e^{v_N}) + 0.57722\ldots, \tag{28}$$

which is simply the inclusive value index (apart from Euler's constant, 0.57722...).

The important point is that we must take into account both the discrete and continuous aspect of the decision problem and the stochastic nature of the decision. One way of doing this is to calculate the compensation which equates the expected values of the indirect utility functions. It is easy to see the implications of this in the extreme corner solution context. Suppose we are concerned with evaluating the benefits from an improvement in quality at an individual site - say, site 1. Thus, b_1 changes from b_1' to b_1'' while $b_2,...,b_N$ and $p_1,...,p_N$ remain constant.

If we knew for certain whether or not each individual would select site 1, these welfare measures would be straightforward to calculate. They would be the sum of the compensation over individuals who chose site 1, where the compensations are defined on the conditional indirect utility functions such that

(29) $$v_1(p_1,b_i'',y-C) = v_1(p_1,b_1',y).$$

But some individuals will and some will not visit site 1 and we can only predict the probabilities of site selection. And, of equal importance, these probabilities will themselves be functions of the qualities (and prices). Equation (27) suggests that we need to weight the conditional indirect utility functions by the probabilities of choosing different sites. (Hanemann (1984) suggests the possibility of using, instead, moments of the induced distribution on the compensating variation as a useful welfare measure.)

The extension to the general corner solution model is intuitively, if not analytically, clear. Here conditional indirect utility functions are defined for all combinations of choices of sites. There will, for example, be an indirect utility function conditioned on the individual choosing nonzero trips to sites 1,2,and 3, but not 4 through N. This will differ for example, from the indirect utility function conditioned on the choice of sites 1,2 and 4, but not 3, or 5 through N. Additionally the conditional demand function for site 1 will differ depending on which additional sites are chosen.

By analogy to the above, welfare measures will require the assessment of the probability of choosing each possible combination of sites as weights for the indirect utility functions conditioned on site choices. This complexity stems from the very nature of the recreational decision process. The benefits which an individual derives from an environmental quality change at some site or group of sites is dependent on whether or not, and at what level, he visits those sites. But this latter mixed continuous-discrete choice is itself a function of quality characteristics.

Some Estimation Examples

Our ultimate intent is to undertake the estimation of each of the above described models (which is capable of valuing site characteristics) using a common data set. The purpose is not to compare the benefit estimates which each approach produces, for such comparisons can never be decisive in any way. Instead we hope simply to demonstrate how each approach gets estimates - to reveal data requirements, necessary estimation techniques, and the practical problems which arise in the estimation process. Of most importance, we wish to determine how useful each approach is in providing answers to policy questions.

Unfortunately we have not yet completed this portion of our task. Of the four general approaches (hedonic travel cost, multinomial shares, discrete choice, and general corner solution), we have completed only two and have estimated the first stage of a third. In what follows we present the results of two versions of the hedonic travel cost model (as presented in Brown and Mendelsohn, 1984, and in Mendelsohn, 1984) and a rather elaborate discrete-continuous choice model (from Bockstael, Hanemann and Strand). The fact that these two are the first to be completed is no accident. They have in their favor one very important quality. Both can be estimated from readily available economic computer software packages. The hedonic travel cost approach is by far the simplest. The first version relies only on OLS estimation techniques, although the second adds a fairly complex Box-Cox transformation. The discrete choice models of Caulkins and Feenberg and Mills requires a multinomial logit and the more elaborate discrete-continuous choice model estimated here requires access to a Tobit type routine (or a general maximum likelihood algorithm) as well.

The approach which is most preferred theoretically is by far the most difficult to estimate. One way to handle the general corner solution model is to estimate the parameters in the direct utility function by maximizing a likelihood function composed of the Kuhn Tucker conditions. By choosing a utility function and error structure, we were able to obtain significant parameter estimates with expected signs. This gives us the direct utility function as a function of these parameters, number of visits, quality of sites, characteristics of the individual and the error structure. However, in a corner solution world, such information is not easy to transform into demands functions for prediction or into indirect utility functions for welfare analysis. While work is continuing in this area, we present the results of our estimation of the other two models.

The data set we use was collected by EPA in 1975 and includes information on recreational swimming at Boston area beaches. The data set contains information on both participants and nonparticipants, as it is based on random household interviews in the Boston SMSA. For each participant, a complete season's beach use pattern is reported, including the number of trips to each beach in the Boston area. We have objective measures of water quality for 30 beach sites. It should be noted that, participants in this data set, like other data sets of its kind which we have encountered, tend to visit more than one site but far less than all sites available.

1. Discrete-Continuous Choice Model

The multiple site recreational demand model estimated by Bockstael, Hanemann and Strand has two components. The first is the macro-decision: does an individual participate in the activity of interest (swimming at beaches in the Boston-Cape Cod area) and if so how many trips does he take in a season? The second component is a site allocation decision: on each choice occasion, which site does he visit? Because the micro decision generates information necessary for estimation of the macro decision, we deal with the micro decision first.

The first part of the model involves the estimation of the household's choice among sites. The indirect utility associated with choosing the i^{th} site is some function Of z_i, a vector of attributes of the i^{th} alternative,, so that $v_i^* = v_i(z_i) + \varepsilon_i$ The random component is additive and attributed to the systematic, but unmeasurable, variation in tastes and omitted variables. If the ε's are independently and identically distributed with type I extreme value distribution (Weibull), then we have a multinomial logit model. However, the multinomial logit implicitly assumes independence of irrelevant alternatives, i.e. the relative odds of choosing any pair of alternatives remains constant no matter what happens in the remainder of the choice set, Thus, this model allows for no specific pattern of correlation among the errors associated with the alternatives; it denies - and in fact is violated by - any particular similarities within groups of alternatives.

McFadden (1978) has shown that a more general nested logit model specifically incorporating varying correlations among the errors associated with the alternatives can also be derived from a stochastic utility maximization framework. If the ε's have a generalized extreme value distribution then a pattern of correlation among the choices can be allowed. Given the probabilistic choice model

(30) $$P_i = \frac{e^{v_i} G_i(e^{v_1}, \ldots, e^{v_N})}{G(e^{v_1}, \ldots, e^{v_N})}$$

where G_i is the partial of G with respect to the i^{th} argument and $G(e^{v_1}, \ldots, e^{v_N})$ has certain properties which imply that

(31) $$F(\varepsilon_1,\ldots,\varepsilon_N) = \exp\left\{-G(e^{-\varepsilon_1},\ldots,e^{-\varepsilon_N})\right\}$$

is a multivariate extreme value distribution. When $G(e^{V_1},\ldots,e^{V_N})$ is defined as Σe^{V_i}, then the model reduces to the ordinary multinomial logit (MNL) desribed above. However when

(32) $$G(Y) = \sum_{m=1}^{M} a_m \left(\sum_{i \in S_m} e^{V_i/(1-\sigma_m)}\right)^{1-\sigma_m}$$

where there are M subsets of the N alternatives and $0 \leq \sigma_m < 1$, then a general pattern of dependence among the alternatives is allowed. The parameters σ_m can be interpreted as indices of the similarity within groups.

The GEV model is useful when alternatives group themselves in obvious patterns of substitutability. It is appropriate because the results of an MNL will be invalid if such a pattern actually exists. It is convenient because it reduces the number of alternatives included at each stage.

The Boston data is particularly amenable to GEV estimation. Within the thirty sites, eight are beaches at fresh water lakes and twenty-two are salt water beaches. It would seem reasonable to suppose that the odds of choosing fresh water site A over salt water site B will be disrupted by the addition of another fresh water lake site. Put another way, fresh water and salt water sites are probably viewed as closer substitutes within groups than across groups.

The GEV model allows us to view individuals (a) as choosing between fresh and salt water and (b) as choosing among fresh water sites conditioned on the fresh water choice and choosing among salt water sites conditioned on the salt water choice. In actuality, the problem is set up so that the individual chooses the "best" within the group of salt water sites and the "best" within the group of fresh water sites and then chooses between these two "best" alternatives on each choice occasion.

To make the estimation process explicit, let us consider the following form of v_{im}

(33) $$v_{im} = \theta' Z_{im} + \psi' W_m$$

where the Z's denote attributes associated with all sites and the W's are associated solely with the salt water-fresh water choice, i indexes the site and m indexes the salt or fresh water alternative. Also let us assume that σ_m is identical within all groups and equal to σ. Define the "inclusive value" of group m as

(34) $$I_m = \ln\left(\sum_{i \in S_m} e^{\theta' Z_{im}/(1-\sigma)}\right).$$

NOW, the probability of choosing site i conditioned on the salt/fresh water choice is

(35) $$P_{i|m} = \frac{e^{\theta' Z_{im}/(1-\sigma)}}{\sum_{k \in S_m} e^{\theta' Z_{km}/(1-\sigma)}}$$

and the probability of making the salt (or fresh) water choice is

(36) $$P_m = \frac{e^{\psi' W_m + (1-\sigma) I_m}}{\sum_{j=1}^{M} e^{\psi' W_j + (1-\sigma) I_j}} .$$

These probabilities can be estimated using MNL procedures. First, the $P_{i|m}$ are estimated with M independent applications of the multinomial logit (where M = 2 here - one for salt water beaches and one for fresh water beaches). Note that at this stage θ is not recoverable, but can be estimated only up to a scale factor of $1-\sigma$. From the results of (35), the inclusive prices (34) are calculated and incorporated as variables in the second level of estimation (36). Here the ψ's and the σ are estimated. A σ outside the unit interval is inconsistent with the underlying utility theoretic model and suggests misspecification.

In choosing among sites, the determinants of most interest are the site characteristics which vary over alternatives and the costs of gaining access to sites. The quality variables chosen for this model include environmental indicators such as oil, turbidity, fecal coliform, chemical oxygen demand and temperature. Three other variables are identified as potentially valuable in the site choice model, each of which is a restricted variable of sorts. The variable "Noise" was set to one for all beaches which were in particularly noisy, congested areas close to freeways (zero otherwise). The variable "Ethnic" was set to one if the beach was especailly popular with a particular ethnic group and the individual was not of that group (zero otherwise). Several beaches were so designated in the study. Finally "Auto" was set to one if a beach was not accessible by public transportation and the household did not own a car.

Because of the nature of the logit model, variables which are present in the indirect utility function but do not change across alternatives (i.e. individual specific) tend to cancel out upon estimation - that is, their coefficients cannot be recovered. This is true unless it is argued that an alternative specific variable has a different effect depending on the value of a socioeconomic variable, in which case the two variables could be entered interactively.

Income is a special individual specific variable because we know from utility theory that income and price must enter the indirect utility function in the form Y - p. Thus if Y - p_i enters linearly into v_i, income will cancel out upon estimation, but the coefficient on price will be income's implicit coefficient as well. This will be important in calculating benefits.

Estimation of the second stage of the model requires the calculation of inclusive values from each of the first stage estimations, where the inclusive price is as defined in (34). This "inclusive value" captures the information about each group of sites in Stage I. Thus if water quality were to change at some sites, the inclusive values would change. Additionally, we postulate that other variables besides the inclusive values may enter at this stage - variables which affect the salt-fresh water decision but do not vary over alternatives within each group. Also, since the fresh-salt water decision is dichotomous, it is straightforward to enter individual specific variables which we believe may affect salt water and fresh water decisions differently. Besides a constant term and the inclusive price, we include the size of the household, the proportion of children and whether or not the household has access to a swimming pool.

Table 1 presents the estimated coefficients and test statistics for the first stage of the GEV model and Table 2 presents the second stage results. Goodness of fit measures for logit models are not especially decisive. For each model we present Chi-square statistics based on likelihood ratio tests. In each case the statistic is significant at the 1% level of significance.

In the first stage of the GEV, the estimated coefficients on quality characteristics all are significant at the 5% significance level and of the expected sign (with the possible exception of temperature and turbidity in the fresh water equation), Additionally, individuals (ceteris paribus) visit closer beaches, avoid noisy areas and are discouraged by beaches heavily pospulated by ethnic groups different from their own. Individuals who do not own cars are less likely to visit beaches not serviced by public transportation.

From the first stage results the "inclusive" values were calculated and introduced in stage two. The inclusive value term captures the effect of all of the variables used to explain site choice. In our problem, $1 - \sigma$, equals .854 implying a σ of .146, which is significantly different from both 0 and 1. This indicates fresh and salt water sites are considered significantly different, but all fresh water sites are not viewed as perfect substitutes for one another and neither are all salt water sites. Thus we can expect that there are some gains from using the GEV

TABLE 1: First Stage GEV

Model Estimates of Choice Among Freshwater and Saltwater Beaches

Boston - Cape Cod, 1975

Beach Characteristic	Saltwater Estimate (t-ratio)	Freshwater Estimate (t-ratio)
Oil	-.036 (-10.01)	-.100 (-2.62)
Fecal Coliform	-.049 (-4.12)	-.486 (-5.47)
Temperature	-.056 (-5.32)	-.281 (-3.58)
COD	-.022 (-17.67)	-.169 (-14.31)
Turbidity	-.047 (-8.48)	.273 (9.10)
Noise	-.109 (-9.90)	-.938 (-8.47)
Public Trans.	-1.103 (-12.91)	-1.275 (-4.07)
Beach Ethnicity	-1.784 (-27.58)	-1.321 (-5.51)
Trip Cost	-.572 (-35.89)	-2.166 (-26.61)
Likelihood	-10850.	-896.
Chi-squared with 9 degrees of freedom	4084.2	1804.7

TABLE 2

Second Stage GEV Model Estimates of Choice between Saltwater and Freshwater Beaches

Boston - Cape Cod, 1975

	Constant	Inclusive Price $(1-\sigma)$	No. of People in Household	% of Children in Household	Access to Swim. Pool
Estimated Coefficient	16.520	.854	-.162	.420	,861
(t-ratio)	(22.9)	(23.6)**	(-10.9)	(2.33)	(9.16)

Likelihood = -1780.

Chi squared with
5 degrees of freedom = 3421.0

* t-ratios in parentheses

** This t-ratio tests significant difference from zero. A more appropriate test is significant difference from 1; the relevant t- ratio is -4.044.

specification. Because of the way in which the constant term, household size, percent children, and swimming pool are entered into the estimation, their coefficients reflect the log of the odds of choosing a salt water site over a fresh water site. Thus larger families tend to go to lakes but families with a larger portion of children tend to go to salt water beaches. Those who have access to a swimming pool are more likely to visit salt water beaches. The constant term suggests that, ceteris paribus, people prefer salt water beaches.

The second part of the model is a single activity model of swimming participation. While several discrete-continuous methods are available, we use the Tobit model which presumes that individual's decisions can be described as

$$
\begin{aligned}
x_i &= h(z_i) + \delta_i \quad && \text{if } h(z_i) + \delta_i > 0 \\
x_i &= 0 && \text{if } h(z_i) + \delta_i \leq 0.
\end{aligned} \tag{37}
$$

and that the decision of whether or not to participate and how much to participate are dictated by the same forces. The likelihood function for model is

$$L_T = \prod_{i \in s} \frac{(-h_i/\sigma)}{\sigma} \prod_{i \notin s} F(-h_i/\sigma) \tag{38}$$

where s is the set of individuals who participate. It was determined that the following household characteristics were most likely to affect this decision:

income
size and composition of household
education
length of work week of household head
ownership of water sports equipment.

Additionally, we would wish to include variables reflecting the cost and quality of the swimming activities available. Herein lies one of the major difficulties with this "second best," two part approach. How does one choose appropriate variables for the cost and quality of swimming excursions, if those trips are or can be taken to different sites with different costs and quality characteristics? Ideally the decision of how much and where to go should be modelled simultaneously as in the corner solution model. However, the discrete choice models are unable to handle these problems simultaneously and require some approximations.

Indeed, we wish to include variables which reflect the quality and costs of the best alternatives for each individual, not necessarily the characteristics of the closest site or the average characteristics over sites. The inclusive value concept has an appealing interpretation since it represents, in a sense, the value of different alternatives weighted by their probabilities of being chosen. Defining an inclusive value from both stages of the GEV estimation gives us

$$I_p = \ln\left[\sum_{j\in J_S} e^{v_j} + \sum_{j\in J_F} e^{v_j}\right] \tag{39}$$

where J_S is the set of salt water sites, J_F is the set of fresh water sites and $v_j = \theta' Z_j + \psi' W_j$ where the Z's are explanatory variables in the first stage and the W's are explanatory variables in the second stage.

Inclusion of I_p in our macro allocation model is intuitively appealing but not perfectly correct. I_p, after all, is defined on choice occasions and the macro allocation decision is an annual or seasonal decision. In fact, there is no obvious way to make this model, or any of the related models, perfectly consistent between micro and macro decisions as well as economically plausible. Nonetheless we hope it offers us a good, albeit ad hoc, reflection of the value of the swimming alternatives available to the individual. It is, however, not consistent with a McFadden type utility theoretic model, and as such, its coefficient is not theoretically bounded by zero and one.

The model includes income, household size, household composition, a restricted variable for ownership of specific water sports equipment and the inclusive value variable discussed above. The results are presented in Table 3. Other variables such as education and length of work week were not significantly different from zero by any reasonable test in the models employed, nor did their exclusion significantly

TABLE 3

Estimates of Tobit Model of Boston
Swimming Participation and Intensity

Variable	Tobit Estimates	Initial Value (OLS estimates)
Constant	26.01 (2.57)*	35.98 (4.59)
"Inclusive Value"	.897 (1.86)	1.02 (2.74)
Income	-1.19 (-.56)	-.07 (1.79)
Size of Household	-24.10 (-2.76)	-8.1 (-2.08)
Percent Children	-6.18 (-1.22)	-14.71 (-2.02)
Water Sports Equipment	13.05 (3.44)	6.42 (2.05)

Chi-Squared statistic = 262.

* t-ratios in parentheses

model are combined with site qualities, individuals' costs and other variables to predict each household's probability of visiting each site. A predicted probability can be interpretted as a predicted share of the household's total trips. Thus a change in the quality at one or more sites can change a) the total number of tips taken, (b) whether or not a household participates in the recreational activity, and c) the allocation of trips among sites.

The ultimate purpose of the modelling effort however is to estimate the benefits associated with improvements in water quality.

In our problem the expected value of the indirect utility function can be shown to equal

(40) $$V(p^0,b^0,y) = \ln G(e^{V_1^0},\ldots,e^{V_N^0}) + k$$

where k is a constant.

Now consider a change in prices and quality from (p^0,b^0) to (p^1,b^1). The C' measure defined earlier is given by

(41) $$V(p^0,b^0,y) = V(p^1,b^1,y-C^1)$$

or

(42) $$\ln G(e^{V_1^0(y,z^0,w^0)},\ldots,e^{V_N^0(y,z^0,w^0)}) = \ln G(e^{V_1^1(y-c^1,z^1,w^1)},\ldots,e^{V_N^1(y-c^1,z^1,w^1)}).$$

There is no closed form solution for compensating variation in this case, but we can approximate the compensating variation of a change form (p^0,b^0) to (p^1,b^1) by

(43) $$CV \approx \left(\sum_{m=1}^{2} e^{\psi' w_m^0 + (1-\sigma) I_m^0} - \sum_{m=1}^{2} e^{\psi' w_m^1 + (1-\sigma) I_m^1}\right) \Big/ \sum_{m=1}^{2} \gamma_m e^{\psi' w_m^1 + (1-\sigma) I_m^1}$$

where m = 1,2 denotes the salt and fresh water alternatives, (W_m^o, I_m^o) and (W_m^1, I_m^1) represent values of variables before and after the policy change respectively, and γ_1 and γ_2 are the implicit income coefficients in the salt and fresh water models.

The calculation of CV according to (43) yields an estimate of the expected compensating variation per choice occasion for the household. To obtain annual or seasonal benefit estimates this number must be multiplied by the predicted number of trips the individual takes. One should note that even if the individual takes no more trips in response to the quality change (either because he is constrained or because a more substantial quality change is necessary to increment the number of trips), the benefits of improvements are still measureable. That is, even if a quality change is insufficiently large to prompt an individual to alter his behavior in any way, the benefits he experiences if he is a user of the improved sites can be calculated.

In Table 4 the estimated benefits (in 1974 dollars) of a series of hypothetical water quality changes are reported. The hypothetical water quality changes introduced include a 10% and a 30% reduction in each of the following water quality parameters individually: oil, chemical oxygen demand (COD) and fecal coliform. These reductions were introduced uniformly across all sites. Also in Table 4 is reported the results of a 30% reduction at all sites in oil, turbidity, COD and fecal coliform simultaneously. This figure can be compared to the same sort of pollutant reductions if they affect only beaches in Boston harbor. Reductions in pollutants at downtown Boston beaches (8 of the 30 sites) generate more than half the benefits reported when all sites are uniformly improved.

These examples are offered to demonstrate the sorts of questions which can be answered with a model such as the one estimated here. The model is admittedly a "second best" model; it pieces together relevant aspects of the recreational decision problem in a somewhat ad hoc way, not completely consistent with any underlying story of utility maximization. While only an approximation, however, the

TABLE 4

Average Compensating Variation Estimates of Specific Reductions in Pollutants at Boston Area Beaches (in 1974 dollars)

	10% reduction at all sites		30% reduction at all sites	
	per choice occasion	per season	per choice occasion	per season
oil	$ .05	$ .96	$ .20	$4.66
COD	.12	2.65	.29	7.15
fecal coliform	.-2	.19	.12	2.85

	30% reduction at all sites		30% reduction at downtown Boston Beaches	
	per choice occasion	per season	per choice occasion	per season
oil, turbidity, COD and fecal coliform	$.50	$12.04	$.27	$6.13

model does attempt to capture all aspects of the individual's recreational decision.

2. The Hedonic Travel Cost Model

The only other approach for which we have completed estimation results is the hedonic travel cost method. Unfortunately, we encountered several difficulties, some of which may be associated with the nature of our data and the recreational activity we are studying and some of which is no doubt due to our lack of experience with the approach. Nonetheless we present our results, hoping to solicit some guidance and stimulate some discussion.

We chose to estimate the model for the subset of saltwater, sites since it seems more likely that good results could be obtained by excluding the 8 very different fresh water sites. The first difficulty we encountered relates to the nature of the observed site choice decisions in our data set and the implicit assumptions of the hedonic travel cost model (HTC). Past HTC applications have implicitly assumed that individuals visit only one site, yet about three-fourths of the participants in the Boston survey visited more than one site. We skirted the problem, perhaps Incorrectly, by including different site choices by the same individual in the regressions as additional observations (in effect as though they were site choices by different individuals). By doing this we gained the added benefit of more variation in sites visited by individuals from the same origin.

Following the approach prescribed by Brown and Mendelsohn, we chose the two most important environmental quality indices (oil and COD) and ran linear regressions of costs on site characteristics for each of 25 origins. The site characteristics are indexed here such that increasing values imply improving water quality to facilitate interpretation. We initially attempted this on the 93 smaller origin zones but found we had so little variation in site choices that regressions were infeasible.

Given the linear functional form of the Brown and Mendelsohn application, the hedonic prices of oil and COD are the estimated coefficients of the regression,

$$C_i = \beta_0 + \beta_1 O_i + \beta_2 D_i + e_i$$

where C_i = costs, O_i = an index of the absence of oil and D_i = an index of the absence of COD. The results of these regressions produced 50 "hedonic prices" (coefficients) only 7 of which were positive and significantly different from zero. In contrast, 23 of the 50 are negative and significantly different from zero,

The marginal value functions for quality characteristics are then estimated by regressing these derived hedonic prices for individuals from each origin to each site on the level of the quality characteristics at the relevant site and several individual related variables. These variables included income and the ethnic dummy variable which had turned out to be important in the discrete-continuous choice model. We also included an instrumental variable for the number of trips the indivdual took, since this variable was included in the Brown and Mendelsohn application. As in that paper, trips were initially regressed on the other individual-specific variables (ethnic dummy and income) as well as dummy variables for origins. Then the predicted values were included in the following marginal value functions for each characteristic

(45) $$PO_i = \alpha_0 + \alpha_1 O_i + \alpha_2 D_i + \alpha_3 y_i + \alpha_4 E_i + \alpha_5 \hat{X}_i + u_i$$

and

(46) $$PD_i = \gamma_0 + \gamma_1 O_i + \gamma_2 D_i + \gamma_3 y_i + \gamma_4 E_i + \gamma_5 \hat{X}_i + w_i$$

where PO_i and PD_i are the derived prices of improvements in oil and COD levels, y_i is income, $\hat{X}_i$ is predicted visits and the E_i is the ethnic dummy.

An important question arose at this point. Since not all hedonic prices from the first stage were positive and even fewer were significant and positive, we were uncertain as to whether observations on all prices should be included in the final stage demand function. The results of two separate approaches are reported in Table 5. The first set of characteristics demand functions includes only those

TABLE 5

Demand for Characteristics Using the Hedonic Travel Cost Approach
(Linear hedonic equation, inverse demand function)

Regressions include only positive prices:

$$\text{Price Oil} = \underset{(4.90)^{**}}{.15} + \underset{(11.97)}{.007}\ \text{Oil}^* + \underset{(2.46)}{.0004}\ \text{COD}^* - \underset{(-6.28)}{.064}\ \text{Ethnic} + \underset{(4.64)}{2.9\times10^{-8}}\ \text{Inc} - \underset{(-50.64)}{.011}\ \widehat{\text{Visits}}$$

$$\text{Price COD} = \underset{(1.56)}{.007} + \underset{(2.12)}{.00005}\ \text{COD} + \underset{(10.4)}{.001}\ \text{Oil} - \underset{(-2.83)}{.004}\ \text{Ethnic} + \underset{(4.74)}{4.5\times10^{-9}}\ \text{Inc} - \underset{(-22.33)}{.0007}\ \widehat{\text{Visits}}$$

Regressions include all prices:

$$\text{Price Oil} = \underset{(1.77)}{.06} + \underset{(2.32)}{.0015}\ \text{Oil} + \underset{(3.17)}{.0005}\ \text{COD} + \underset{(1.94)}{.024}\ \text{Ethnic} + \underset{(3.05)}{2.19\times10^{-8}}\ \text{Inc} - \underset{(-15.98)}{.0035}\ \widehat{\text{Visits}}$$

$$\text{Price COD} = \underset{(-.97)}{-1624} - \underset{(-11.1)}{89.4}\ \text{COD} + \underset{(15.26)}{485.1}\ \text{Oil} - \underset{(-11.75)}{7311.7}\ \text{Ethnic} + \underset{(5.78)}{.002}\ \text{Inc.} - \underset{(-34.87)}{375.5}\ \widehat{\text{Visits}}$$

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* oil and COD denote indices which increase with declining levels of these pollutants.

** t statistics are in parentheses

observations for which we have positive prices. The second set includes all observations. The functions estimated on reasonable prices (the positive ones) did not produce negative coefficients on own-prices. In both cases, both price coefficients were significantly different from zero and positive. Only when negative prices were included did we estimate a negative demand slope - and then only for COD.

Given the rather discouraging results using this form of the model, we chose to follow the estimation procedures presented in Mendelsohn (1984). Here the first stage regressions (i.e. the hedonic price equations) were nonlinear Box-Cox transformations. We estimated

$$\frac{c_i^{\lambda}-1}{\lambda} = \beta_0 + \beta_1 \left(\frac{O_i^{\lambda}-1}{\lambda}\right) + \beta_2 \left(\frac{D_i^{\lambda}-1}{\lambda}\right) + e_i \qquad (47)$$

which allowed some flexibility in form as well as a "hedonic price" which was a function of characteristic levels. Characteristics' prices can not be determined directly from these results, but must be constructed from the derivation of equation (47). There are, however, 25 price gradients for each characteristic. Only 11 of the 25 price gradients for COD produced positive prices and 16 of the 25 price gradients for oil produced positive prices.

The next step of this procedure requires estimating instrumental variables for characteristic prices (in addition to visits) before including these prices in the characteristics demand function. Following Mendelsohn, the constructed prices were regressed on income, the ethnic dummy and site dummies producing predicted prices. This procedure did not appreciably increase the number of positive prices, however.

The final step of the procedure involves the estimation of characteristic demand functions with quantity on the left hand side as opposed to price. The forms of these functions are

$$O_i = \alpha_0 + \alpha_1 \hat{PO}_i + \alpha_2 \hat{PD}_i + \alpha_3 Y_i + \alpha_4 E_i + \alpha_5 \hat{X}_i + u_i$$
$$D_i = \gamma_0 + \gamma_1 \hat{PO}_i + \gamma_2 \hat{PD}_i + \gamma_3 Y_i + \gamma_4 E_i + \gamma_5 \hat{X}_i + w_i.$$

Again we ran one set of regressions on observations which had only positive predicted prices and a second set on all observations including negative prices. The results are reported in Table 6.

Once again, those regressions which included only positive prices were unsatisfactory. The own price coefficient was posiive and significant for oil and insignificant (although negative) for COD. When both positive and negative prices were included, however, both the oil and COD regressions behaved respectably. For example, in the oil equation, the demand for cleaner water (less oil) decreased with the "price" of cleaner water (in terms of oil) increased with the "price" of cleaner water (in terms of COD), increased with income and decreased with total number of trips taken. In the COD equation, the demand for less COD decreased with the price of less COD and increased with the price of less oil. However the signs on income and total (predicted visits) were reversed from the previous results.

There is an obvious difficulty in the above results. 'We are only able to estimate negative demand slopes when we include nonsensical (negative) prices. One can have little faith in the results of such regressions. Nonetheless we used the one downward sloping demand function in the first set of results (linear hedonic price and inverse demand function procedure) and calculated the consumer surplus (per visit?) of a 10% change in COD. The result was an embarrassingly large number - $39,529. Not trusting demand functions estimated from negative prices, we then calculated welfare measures using the demand estimation which generated a negative (albeit insignificant) price slope from the second procedure (Box-Cox hedonic equation, quantity-dependent demand). The consumer surplus of a 10% change in COD was calculated to be $450 (per visit?).

The application of the hedonic travel cost model to the Boston data set was far from successful. The less than satisfactory results at each stage of the procedure may result from our misunderstanding of the model. Alternatively, it could be that

TABLE 6

Demand for Characteristics Using the Hedonic Travel Cost Approach
(Nonlinear hedonic equation, quantity dependent demands)

Regressions include only positive prices:

$$\text{Oil}^* = \underset{(43.94)^{**}}{36.30} + \underset{(8.29)}{7.93}\,\widehat{\text{Price}}\,\text{Oil} + \underset{(1.91)}{3.89}\,\widehat{\text{Price}}\,\text{COD} + \underset{(5.26)}{1.6\text{x}10^{6}}\,\text{Inc} + \underset{(2.05)}{1.3}\,\text{Ethnic} + \underset{(6.1)}{.08}\,\widehat{\text{Visits}}$$

$$\text{COD}^* = \underset{(19.27)}{64.39} - \underset{(-.12)}{.98}\,\widehat{\text{Price}}\,\text{COD} + \underset{(1.56)}{6.03}\,\widehat{\text{Price}}\,\text{Oil} - \underset{(-3.91)}{4.8\text{x}10^{6}}\,\text{Inc} + \underset{(1.32)}{3.4}\,\text{Ethnic} - \underset{(-3.98)}{.206}\,\widehat{\text{Visits}}$$

Regressions include all prices:

$$\text{Oil} = \underset{(110.9)}{44.54} - \underset{(-2.57)}{1.17}\,\widehat{\text{Price}}\,\text{Oil} + \underset{(6.68)}{8.79}\,\widehat{\text{Price}}\,\text{COD} + \underset{(9.2)}{1.9\text{x}10^{6}}\,\text{Inc} - \underset{(-5.19)}{1.17}\,\text{Ethnic} - \underset{(-17.34)}{.11}\,\widehat{\text{Visits}}$$

$$\text{COD} = \underset{(15.11)}{24.05} - \underset{(-3.27)}{17.06}\,\widehat{\text{Price}}\,\text{COD} + \underset{(2.40)}{4.33}\,\widehat{\text{Price}}\,\text{Oil} - \underset{(-5.01)}{4.1\text{x}10^{6}}\,\text{Inc} + \underset{(25.96)}{34.25}\,\text{Ethnic} + \underset{(14.62)}{.37}\,\widehat{\text{Visits}}$$

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* oil and COD denote indices which increase with declining levels of these pollutants.

** t statistics are in parentheses

the approach is appropriate only under very restrictive conditions which are violated by many real world valuation problems.

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THE TOTAL VALUE OF WILDLIFE RESOURCES: CONCEPTUAL AND EMPIRICAL ISSUES

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THE TOTAL VALUE OF WILDLIFE RESOURCES:
CONCEPTUAL AND EMPIRICAL ISSUES

I. INTRODUCTION

A major issue in benefit-cost analysis is how to conceptualize the total benefits from environmental assets in a consistent and usable manner. Many practitioners seem to agree that these benefits can be roughly grouped under the general headings of "use" and "intrinsic" values (see Fisher and Raucher 1983). Use benefits are associated with the actual use of an environmental asset and intrinsic benefits comprise a catch-all category for all nonuse benefits such as option values and existence benefits. However, considerable confusion exists regarding the exact distinction between these categories. In addition, the components of the intrinsic benefit category have not always been clearly defined in a way that is internally consistent.

Partly because of these conceptual problems, the valuation of resources often focuses on consumptive uses such as hunting, fishing and trapping. Esoteric benefits such as existence values have been almost completely ignored and even nonconsumptive uses like viewing wildlife are rarely studied.[1/] The purpose of this paper will be to identify the components of total value and to clarify the definitions of these various components in the context of wildlife

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1/ Recent studies by Brookshire, Eubanks and Randall (1983), Stoll and Johnson (1984) and Walsh, Loomis and Gillman (1984) are exceptions to this statement.

valuation.[2/] Specifically, the various types of use values will be discussed and a theoretic definition of existence value will be proposed. Further, an application to valuing two of Wisconsin's endangered species of wildlife will be presented.

II. CONCEPTUAL FRAMEWORK

A TRADITIONAL NOTION OF VALUE

Early benefit-cost analyses focused merely on the user benefits associated with environmental assets. Later theoretical analyses incorporated the concept of option value which was first introduced by Weisbrod (1964). The option value concept was subsequently refined and clarified (Bishop 1982; Freeman 1984; Graham 1981; Hanemann 1985; and Smith 1983 and 1984a). Option value is an adjustment to the monetary measure of welfare to reflect the uncertainty consumers face when future states of the world are unknown. Recent developments indicate that option value may be either positive or negative. Thus, the maximum that an individual would be willing to pay to insure that an environmental asset will be available in the future is termed "option price" and consists of the expected value of Hicksian surplus and option value, where option value may be positive, negative or zero.

Consider the case of elk hunting. The choice problem faced by an elk hunter, under conditions of certainty, can be stated as

$$\max_{X,Z} U(X,Z) \qquad (1.1)$$

$$\text{s.t. } P_X X + P_Z Z \leq I \qquad (1.2)$$

2/ The conceptual approach developed in this paper is applicable to the valuation of other types of nonmarket resources when the peculiarity of the resource in question is taken into consideration.

where $U(\cdot)$ is a utility function, X is elk hunting, Z is a vector of market goods and services, P_x is the price of elk hunting, P_z is a vector of market prices and I is income. The hunting argument is typically measured in some unit of time, e.g., trips, days, etc.[3/] The cost of a unit of hunting is interpreted as the price of hunting.

Assuming this maximization problem is well behaved and can be solved, an indirect utility function can be derived:

$$V(P_x, P_z, I) = \bar{U}. \qquad 1.3$$

The reference level of utility is $\bar{U}$. The equivalent variation measure of the total value of elk hunting (β_a) is given by

$$V(P_x, P_z, I-\beta_a) = V(P_x^m, P_z, I)$$

where P_x^m is the lowest price which is high enough that the individual would choose not to hunt. All other prices are held constant at their existing levels. The argument β_a is the maximum that the individual would pay to maintain the opportunity to hunt elk rather than give it up completely.

3/ The important consideration is that people do derive satisfaction from hunting regardless of the units of measure. Thus, we are not overly concerned with the units of measure in the present discussion.

The concepts of option price and option value arise when uncertainty is introduced into the valuation question.[4/] Suppose that it is desirable to know the value that elk hunters place on a hunt in a particular wildlife management area. Individual elk hunters are certain that they will desire to hunt elk in this wildlife management area, but that uncertainty arises as to whether this area will be open to elk hunting due to an administrative snafu. This simple example is equivalent to price uncertainty in a timeless world (see Bishop 1982). Option price in this simple model, under conditions of "supply-side" uncertainty in a timeless world,[5/] is defined by

$$V(P_x, P_z, I-\beta_{op_s}) = \pi V(P_x, P_z, I) + (1-\pi)V(P_x^m, P_z, I) \quad (1.5)$$

where β_{op_s} is a equivalent variation measure of supply-side option price and IT is the probability that the wildlife area will be open for elk hunting. The left-hand side of equation (1.4) can be substituted into equation (1.5) to yield the following relation:

$$V(P_x, P_z, I-\beta_{op_s}) = \pi V(P_x, P_z, I) + (1-\pi)V(P_x, P_z, I-\beta_a). \quad (1.6)$$

Using equation (1.6) and following Bishop (1982), supply-side option value is defined as

$$\beta_{ov_s} = \beta_{op_s} - (1-\pi)\beta_a > 0 \quad (1.7)$$

4/ Our intent is not to make this another paper on option value. This simple example is merely intended to identify the option price concept and to point out when option values occur. In the remainder of the paper we will merely identify where uncertainty can enter the model giving rise to notions of option price and option value.

5/ The distinction between demand-side and supply-side uncertainty has been made by Bishop (1982) and Freemen (1985).

where β_{ov_s} is supply option value and the other symbols are as previously defined. If some of the simplifying assumptions of the current model are relaxed, the sign of supply-side option value is indeterminate (Chavas and Bishop 1984). This result is consistent with the findings of Freeman (1985).

Now assume that elk hunters are uncertain as to whether they will desire to participate in the hunt, but that it is certain that the wildlife management area will be open to hunting. "Demand-side" uncertainty results in a slightly different definition of option price. This is

$$\pi V(P_x, P_z, I-\beta_{op_d}) + (1-\pi) V(P_z, I-\beta_{op_d}) = \pi V(P_x^m, P_z, I) + (1-\pi) V(P_z, I) \qquad 1.8$$

where β_{op_d} is a equivalent variation measure of demand-side option price and π is the probability that the individual will choose to participate in the hunt at any price, i.e., hunting is not an argument in the individual's utility function. The left-hand side of equation (1.4) can be substituted into equation (1.8) to yield the following relation:

$$\pi V(P_x, P_z, I-\beta_{op_d}) + (1-\pi) V(P_z, I-\beta_{op_d}) = \pi V(P_x, P_z, I-\beta_a) + (1-\pi) V(P_z, I). \qquad 1.9$$

This relationship can be used to derive demand-side option value. We will not derive demand-side option value here as it is slightly more complicated than supply-side option value and the derivation is a relatively straightforward application of previous work by Bishop (1982) and Smith (1983). These authors have shown that the sign of option value is indeterminate when an individual's demand is uncertain.

The current model summarizes the simple framework traditionally used for considering consumptive use values for wildlife, e.g., hunting, fishing and trapping. This model is not general enough in that it overlooks individuals who are not hunters, but do participate in other types of uses of wildlife, e.g., viewing, photographing, reading, etc. In addition, consumptive users may also participate in these other activities. These other uses may need to be incorporated specifically as arguments in the utility function as they may be measured in different units than consumptive use or may have different per unit prices, and they may also have different parameters in the utility function. These other uses may also have complementary or substitute relations to consumptive uses. Thus, a total valuation framework is needed which is much broader. This is especially true for species of wildlife that are not hunted, trapped or fished.

AN EXPANDED NOTION OF VALUE

Not only did early benefit-cost analyses focus merely on use benefits, but only a subset of such benefits were actually considered for empirical valuation. This was especially true in regard to the valuation of wildlife resources (Brown and Nawas 1973; Gum and Martin 1975; and Davis 1964).[6/] Only consumptive use values such as hunting and fishing were typically estimated. There are also nonconsumptive use values associated with wildlife. For

6/ This is not to imply that these studies were poorly designed, but that they merely reflect the state of the art of nonmarket valuation at the time they were conducted.

example, people visit National Parks and wildlife sanctuaries with the intent of viewing wildlife. Bird watching is also an activity that some people enjoy. People in the Northwest go out to watch the salmon runs, even if they never plan to fish for salmon. These nonconsumptive uses may be at least as important in value terms as hunting and fishing (see Fisher and Raucher 1983).

There is also a hazy area of use that is not associated with direct contact with wildlife. Many people never come in contact with wildlife in its natural habitat, but they do derive satisfaction from it. Among other activities, they enjoy reading about wildlife, viewing pictures of wildlife, watching television specials about wildlife, and visiting zoos. Another form of indirect consumption arises when people benefit from some types of wildlife research. These indirect users obtain satisfaction from wildlife via the consumption of goods and services that are derived from wildlife.

The choice problem for the elk valuation example can be expanded to incorporate all three categories of use. The new choice problem is

$$\max_{X_i, Z} \; U(X_1, X_2, X_3, Z) \qquad (2.1)$$

$$\text{s.t. } P_x X + P_z Z \leq I \qquad (2.2)$$

where X_1 is consumptive use (hunting), X_2 is nonconsumptive use (viewing, photographing, etc.), X_3 is indirect use, and P_x and X are now vectors that reflect all three categories of use. The other symbols are as previously defined. Any specific individual may participate in any one, or combination of, these uses. We include all three here for expository purposes.

Consumptive uses were referred to as "use" in the preceding section. Nonconsumptive use could involve merely viewing elk and, for a hunter, it could be scouting for elk prior to hunting season. Nonconsumptive use could be measured in some unit of time spent participating in the activity, as is done to measure consumptive use. Indirect use is more difficult to characterize and measure. One approach might be to consider indirect use as a composite good and aggregate the time spent in all types of indirect use. This is not an entirely satisfactory procedure. For example, the consumption of the benefits of wildlife research, very broadly defined, may not be amenable to a time measure. This is an issue that requires further consideration. An additional issue of concern is related to the durability of books, movies, photographs, and the like. It is possible for some types of indirect use to occur even when a species no longer exists. One might argue that the initial cost of durable items fully covers the present value of future uses. If this is the case then only new expenditures would need to be valued.

The total value of elk for an individual who participates in all three types of use is defined as

$$V(P_x, P_z, I-\beta_b) = V(P_x^m, P_z, I) \qquad 2.3$$

where β_b is a equivalent variation measure and P_x^m is the vector of lowest possible prices that are high enough that all three categories of use are zero.[7/] Similarly, the component use values are defined as

$$V(P_x, P_z, I-\beta_1) = V(P_{x_1}^m, P_{x_2}, P_{x_3}, P_z, I) \qquad 2.4$$

$$V(P_x, P_z, I-\beta_2) = V(P_{x_1}, P_{x_2}^m, P_{x_3}, P_z, I) \qquad 2.5$$

7/ It is important to realize that the following condition generally holds:

$$P_x^m \neq [P_{x_1}^m, P_{x_2}^m, P_{x_3}^m].$$

$$V(P_x, P_z, I - \beta_3) = V(P_{x_1}, P_{x_2}, P^m_{x_3}, P_z, I) \qquad 2.6$$

where β_i is the respective equivalent variation measure of value and the superscript m indicates a price such that the respective category of use is zero. Total value (β_b) is generally not the sum of the component use values. This occurs because there may be complementary or substitute relations among the use arguments.

This expanded model highlights the fact that only measuring consumptive use value for a wildlife resource can result in an underestimate of total value. That is, if β_2 and β_3 are positive, then only considering consumptive use value (β_1) will yield an underestimate β_b. (There is not a direct relation between β_a and β_b as they are each defined in a different context.) Thus, it is necessary to consider all categories of use when estimating total value. Even if an estimate of consumptive use value is all that is desired, it is still important to consider the status quo of the other categories of use.

Notions of option price and option value can be developed with respect to each of the three use arguments. For example, uncertainty could arise with respect to the price of any one use argument. Thus, it is not sufficient to only ask whether the uncertainty is on the supply-side or the demand-side. It is also necessary to evaluate the source of the uncertainty. In turn, option value is not merely a concept related to the potential for consumptive use of a resource, but rather is the result of uncertainty wherever it occurs in the choice problem.

Finally, this expanded notion of value may still not be sufficient to conceptualize the total value of a wildlife resource. Values that are not associated with use may also be present.

A NOTION OF NONUSE VALUES

As an outgrowth of the option value discussion, Krutilla (1967) suggested that people may value an environmental asset even though they are sure that they will never personally use the resource in question. This is in direct contrast to use values. Krutilla proposed two types of nonuse values. The first is bequest value and is motivated by a desire to provide some of a resource for future generations. The second category is existence value and arises from the knowledge that a resource merely exists. That is, many people might be willing to pay some positive amount to know that a resource exists, even though they are sure that they will never personally use it. It is also conceivable that users and potential users of environmental assets may possess existence or bequest values over and above their use values. If this is the case, the expected value of consumer surplus is not merely comprised of use values.

Recent theoretical discussions have treated bequests and pure existence as motivations for nonuse values and have referred to the entire category of nonuse values as existence value (Bishop and Heberlein 1984; Fisher and Raucher 1983; McConnell 1983; and Randall 1984). On the other hand, a recent empirical study attempted to differentiate between bequest values and pure existence values (Walsh, Loomis and Gillman 1984).

Individuals who place a value on an environmental asset and are sure that they will never use this resource must be motivated by some form altruism. Bequest values reflect altruism toward future generations. The desire to know that a natural environment merely exists reflects altruism towards nature. Several authors have argued or assumed that the basis for existence value is altruism (McConnell 1983; Randall 1984; and Randall and Stoll 1983). In contrast, Smith (1984b) has alluded that altruism may not be the only motivation for existence values and appears to include indirect use as an additional motivation. Randall (1984) and other authors who have considered the components of total value either include indirect use as a use value as was done in the preceding section or overlook it entirely. This discrepancy is due to a fuzzy definition of the term existence value. The broad definition used by Smith (1984b) answers the practical question of what types of values are missing when valuation studies overlook individuals who are certain to never come in contact with a resource. While this approach has some appeal the narrower definition of existence value may be of more help in the development of appropriate estimates of value.

We argue that the term existence value should be used to refer to nonuse values that arise due to altruistic motives. Thus, existence is a pure public good. Values that arise from indirect contact with a resource will be referred to as indirect use values. We advocate these definitions due to their intuitive and practical appeal. The names provide some insight into the characteristics of the categories. More importantly, there is a theoretical distinction that helps to clarify this definition of existence value. This is the notion of weak complementarity (Freeman 1979; and **Mäler** 1974). Weak complementarity implies that people who do not demand a market good that is dependent on the environmental asset being valued will not be willing to pay any positive amount for the maintenance of the asset. Since there are not any market goods that are related to existence motivations based on altruism, methods of valuation utilizing weak complementarity cannot be used to measure existence values. Furthermore, this definition of existence value will aid in the development of appropriate estimates of value in empirical applications.

That is, we believe that a careful consideration of the components of value and the motivation for values can lead to more precise estimates of value.

MOTIVATION FOR EXISTENCE VALUES

The concept of pure existence value requires careful consideration. Randall (1984) argues that existence values require some type of use behavior in order for individuals to have any knowledge or recognition of a resource. This could be either current use or prior use. Of course, Randall is including what we refer to as indirect use under the heading of use. McConnell (1983) has suggested that information about a resource may come to an individual as a pure public good. For example, environmental groups do a considerable amount of public education to further their causes. State and federal resource agencies also disperse information about the environment that has public good characteristics. Therefore, information about wildlife may be available as a public good. As a result, direct expenditures may not be a prerequisite for pure existence values. On the practical side, and it does appear to be a reasonable assumption that someone who places an existence value on a natural resource will seek to learn more about the resource. At the very least it is plausible that indirect use values may occur simultaneously with existence values for many wildlife resources. In turn, one would expect that an individual who has existence motivations toward a resource is also a current or previous user of the resource in some sense.

Randall and Stoll (1983) have identified three types of altruism that could motivate existence values. These motivations are: interpersonal altruism, intergenerational altruism and Q-altruism. Interpersonal altruism arises from feelings toward individuals in the current generation and intergenerational altruism reflects feelings about future generations. Q-altruism arises from the knowledge of the pure existence of an environmental asset and is not related to other people. Bishop and Heberlein (1984) identified five similar categories of altruistic motives for existence values: bequest motives, benevolence towards friends and relatives, sympathy for people and animals, environmental linkages and environmental responsibility.

Bishop and Heberbein provided the following justifications for each of their suggested altruistic motives for existence values.

> (a) Bequest motives - As Krutilla (1967) argued many years ago, it would appear quite rational to will an endowment of natural amenities as well as private goods and money to one's heirs. The fact that future generations are so often mentioned in debates over natural resources is one indication that their well-being, including their endowments of natural resources, is taken seriously by some present members of society.
>
> (b) Benevolence toward relatives and friends. Giving gifts to friends and relatives may be even more common than making bequests of them. Why should not such goals extend to the availability of natural resources?
>
> (c) Sympathy for people and animals. Even if one does not plan to personally enjoy a resource or do so vicariously through friends and relatives, he or she may still feel sympathy for people adversely affected by environmental deterioration and want to help them. Particularly for living creatures, sympathy may extend beyond humans. The same emotions that lead us to nurse a baby bird or stop to aid a run-over cat or dog may well induce us to pay something to maintain animal populations and ecosystems.
>
> (d) Environmental linkages. A better term probably exists here. What we are driving at is the belief that while specific environmental damage such as acidification of Adirondack lakes does not affect one directly, it is symptomatic of more wide-spread forces that must be stopped before resources of direct importance are also affected. To some extent this may reflect a simple "you've-got-to-stop-'em-somewhere" philosophy. It may also reflect the view that if "we" support "them" in maintaining their environment, "they" will support us.
>
> (e) Environmental responsibility. The opinion is often expressed that those who damage the environment should pay for mitigating or avoiding future damage. In the acid rain case, there may be a prevalent feeling that if "my" use of electricity is causing damage to ecosystems elsewhere, then "I" should pick up part of the costs of reducing the damage.

Accepting the validity of these altruistic motivations is tantamount to acknowledging the potential for existence values. A casual observation might also lead one to suspect that existence values for a major wildlife resource might be positive. In fact, the case studies cited by Fisher and Raucher (1983) indicate substantial existence values for several types of environmental assets, including wildlife.

THOUGHTS ON MODELING EXISTENCE MOTIVATIONS

Becker (1974) and Chavas (1984) have modeled altruism in a general context by incorporating the utility of others as arguments in the utility function of. an altruistic individual. This is a questionable procedure. First, the altruistic individual does not know the utility functions or utility levels of others. Alternatively, an altruist may not feel that it is appropriate to evaluate the satisfaction of others in terms of his or her own utility function. Finally, intrinsic altruism (Q-altruism) toward environmental assets cannot be evaluated in terms of the utility of others.

McConnell has noted that it is only possible to recover a monotonic transformation of an individual's utility function. This means that if a poor person is better-off due to a food program an empirical investigator can only identify that the altruist derives positive marginal utility from the food consumption of the poor person. In turn, it may be sufficient for empirical purposes that the poor person's consumption of food enters as an argument in the altruist's utility function. No evaluation of the poor persons utility is necessary for empirical purposes other than that marginal utility is positive.

A reasonable approach may be to assume that an altruist knows that an altruistic action will lead to an increase in utility for others or will lead to an improvement in the environment. In terms of other people we are merely stating that the marginal utility of an altruistic action is positive. For this case the question becomes one of need and ability to contribute. Most altruistic people probably can arrive at a conclusion regarding their ability to contribute, but may struggle with the question of need of the recipients of the altruistic gesture.[8/] This question of need may be the reason why altruism among individuals who are not closely associated is manifested in private and public organizations. The organization can evaluate need and coordinate altruists. In turn, altruists merely need to know that their actions, or an organization's actions, will make a positive contribution. By positive contribution we mean an increase in someone's utility level or an improvement in the environment.

Consider an action by a public agency that improves elk habitat in Idaho. The primary effect of this action is an increase in the population of elk. Such an increase in population may be indicative of increased opportunities for viewing elk, higher success rates for elk hunters, a stronger and more viable elk population, and a larger elk population base for future users. In this example the population of elk could enter as the altruistic argument in an individual's utility function. Another example is water quality where the quality level could enter as an argument in an altruist's utility function. Recognizing that the average person is not entirely cognizant of water quality indicies or wildlife population levels, a rough approximation to these measures may be the best information that people use to make decisions. All the same,

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8/ Suppes (1966) discusses this type of choice problem in a game theoretic framework.

these types of considerations are extremely important if appropriate measures of value are to be **obtained.**[9/]

A final issue on this topic is that existence is not simply a dichotomous choice. Of course, a resource can either exist or not exist, but when a resource exists there are various levels of existence. This fact is reflected when existence is measured by variables such as a water quality index or wildlife population levels. It seems reasonable to assume that people do recognize that there are differing levels of existence.

All of the preceding discussion has contained the implicit assumption that the marginal existence value of a resource is positive. This is also true of other author's discussions of existence value (See McConnell, 1983). It is possible that for some people the marginal existence value of certain resources may be negative. Consider the case of coyotes in the western United States. Some people may not like coyotes even though they will never come in contact with one. An increase in the population of coyotes may irk these people, thereby leading to a reduction in their level of utility. Alternatively, there may be people who have relatives who are ranchers that are adversely affected by coyotes. In this case, these people may be willing to pay some positive amount just to know that their relatives (the ranchers) will not be bothered by coyotes. Another example is the case of parents who have children who enjoy back-country hiking in places like Yellowstone National Park. The parents might be willing to pay some positive amount to know that grizzly bears do not

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9/ A similar approach was used by Schulze, Brookshire and Thayer (1981). These authors were trying to measure existence value for beauty in National Parks and include a measure of visibility as an argument in their utility specification.

exist in the hiking area posing a threat to their children. These examples suggest that pure existence values may not always be positive.

A MODEL OF TOTAL VALUE

The model developed in this section specifically incorporates nonconsumptive use, indirect use and existence as arguments in an individual's utility function. This model is somewhat similar to one developed by Smith (1984b), but our model incorporates more than one category of use, gives a more precise definition of the existence argument, and highlights an oversight in Smith's development. Using the elk example once again, the choice problem becomes

$$\max_{X_i, Z} U(X_1, X_2, X_3, Z, \gamma) \quad (3.1)$$

$$\text{s.t.} \quad P_x X + P_z Z \leq I \quad (3.2)$$

$$X_i \leq g_i(\gamma) \ \forall \ i \quad (3.3)$$

$$\gamma = \bar{\gamma} \quad (3.4)$$

where γ is the elk population level (existence argument) and $\bar{\gamma}$ is the current population of elk.[10/] The constraint on the use arguments $[g_i(\cdot)]$ could take the form

$$X_i \leq g_i(\gamma) = [I_i(\gamma)]\ C \quad (3.5)$$

10/ Within this simple model the existence argument is represented in a static framework. In reality, individuals probably desire that a resource exists over a number of time periods. There are several ways that existence preferences could be modeled in a dynamic framework. First, one could consider the existence argument to be a vector with the components being indexed over time. A second suggestion would be to index utility functions over time periods. Finally, a third approach would be to combine the first and second suggestions within one model.

and

$$I_i(\gamma) = \begin{cases} 1 \text{ if } \gamma \geq \alpha_i \\ 0 \text{ otherwise} \end{cases} \quad (3.6)$$

where $I_i(\cdot)$ is an indicator function, C is an arbitrarily large constant and α_i is a constant that varies across use arguments. If the population (γ) falls below α_i, there are insufficient animals to support the ith category of use. All other symbols are as previously defined.

We will assume that the marginal utility of existence (γ) is positive and is increasing at a decreasing rate. A practical consideration is that the existence argument enters the utility function so that utility is positive even when existence is zero. Finally, existence will be treated as a pure public good and therefore it is not a choice variable. Once again, a specific individual may participate in any one, or combination of, the three categories of the use. All three are included for expository purposes.

The total value (β_{TV}) of elk is defined as:

$$V(P_x, P_z, \bar{\gamma}, I-\beta_{TV}) = V(P_x^m, P_z, 0, I) \quad (3.7)$$

Here we are comparing expenditures with and without the resource (elk). The total use value $(\beta_{123}$ of elk is defined in a similar manner as was done in equation (2.3):

$$V(P_x, P_z, \bar{\gamma}, I-\beta_{123}) = V(P_x^m, P_z, \bar{\gamma}, I) \quad (3.8)$$

Likewise, the component use values can be defined for the present model:

$$V(P_x, P_z, \bar{\gamma}, I-\beta_1) = V(P^m_{x_1}, P_{x_2}, P_{x_3}, \bar{\gamma}, I) \quad (3.9)$$

$$V(P_x, P_z, \bar{\gamma}, I-\beta_2) = V(P_{x_1}, P^m_{x_2}, P_{x_3}, \bar{\gamma}, I) \quad (3.10)$$

$$V(P_x, P_z, \bar{\gamma}, I-\beta_3) = V(P_{x_1}, P_{x_2}, P^m_{x_3}, \bar{\gamma}, I) \quad (3.11)$$

The β_i's are the respective equivalent measures of use value. As was previously mentioned, there is no a priori reason to believe that the sum of the component use values (β_i's) is equal to total use value. A marginal value of elk hunting (β^*_1) is defined as

$$V(P_x, P_z, \bar{\gamma}, I-\beta^*_1) = V(P^*_{x_1}, P_{x_2}, P_{x_3}, \bar{\gamma}, I) \quad (3.12)$$

where P_{x_1} represents a marginal increase in the price of elk hunting. Similar marginal values can be developed for the other use arguments and for marginal decreases in prices.

A marginal existence value (β^*_{EV}) can now be defined as

$$V(P_x, P_z, \bar{\gamma}, I-\beta^*_{EV}) = V(P_x, P_z, \gamma^*, I) \quad (3.13)$$

where γ^* represents a marginal decrease in the population of elk. Total existence value for a person whose preferences only include existence motivations can be easily defined as

$$V(P_z, \bar{\gamma}, I-\beta_{EV}) = V(P_z, 0, I) \quad (3.14)$$

where the vector $\mathbf{P_x}$ does not enter as an argument because the person is not a user of elk. This is not a typical case since it was argued in preceding sections that a person who has existence motivations for a resource will probably also be at least an indirect user of the resource although existence value may be based on historical use alone.

Total existence value of a resource is not easily defined when a person is both a user of the resource and also has existence motivations. This problem can be portrayed in the context of the current example. That is, the constraint specified in equation (3.5) is binding when the existence argument (elk population) is very small or is zero. The following condition holds when this constraint is binding.

$$\sum_{i=1}^{3} \left(\frac{\partial U}{\partial X_i} \frac{\partial X_i}{\partial \gamma} \right) + \frac{\partial U}{\partial \gamma} \qquad (3.15)$$

As a result it is not conceptually possible to identify a definition for pure existence value in this case. It appears that this result holds regardless of the manner in which existence motivations are modeled as it is impossible to use a resource when it does not exist or the level of existence is at some minimal level. This is an issue that Smith (1984b) appears to have overlooked in his definition of existence value.

This is not a severe limitation for applied policy research since the researcher may only desire to measure marginal changes in existence values or total value. An alternative is to measure a conditional existence value. This value is defined by

$$V(P_x^m, P_z, \bar{\gamma}, I-\beta_{EV}|_{x=o}) = V(P_x^m, P_z, O, I) \qquad (3.16)$$

where prices are such that all categories of use are zero. This conditional existence value turns out to be merely total value (β_{TV}) minus total use value (β_{123}). The prospects for measuring an unconditional existence value are not promising because of the one-way interaction between the use arguments and the existence argument when the constraint in equation (3.5) is binding.

Option price and option value concepts can also be developed with respect to the existence argument if individuals are uncertain as to whether they have existence motivations for elk or if the population level of elk is uncertain. The result, as was previously stated, is that option prices and option values arise when uncertainty enters the valuation question. The important point is that there is no single concept of option price or option value. It is necessary to consider whether the uncertainty is demand-side or supply-side, and consideration must be given to the source of the uncertainty within these two categorizations.

The valuation question is even more complicated than presented here. Each of the four components of value have various features. For example, consumptive use of elk could involve bow hunts, gun hunts, antlerless-only hunts, etc. It is likely that hunters will place different values on each type of hunt and there may be substitute relationships. Nonconsumptive use may involve going out with the intent of viewing elk or incidentally seeing an elk while you are driving or hiking. The four crude groupings of value components are used here to represent on an abstract level the complexity of the valuation question. As noted before, only valuing consumptive uses of a wildlife resource will in general result in an underestimate of total value. Now it is clear that only measuring use values is not sufficient when existence motivations are present. In fact, even if the objective is to measure only one component of value, it is still necessary to consider the other types of values that individuals might place on the resource.

Finally, the discussion in this section was developed under the assumption that the marginal existence value of elk is positive. Appropriate measures of existence value can also be developed for the case where marginal existence value is negative and the definitions would be parallel to the procedures used for the case of positive marginal existence values.

III. EMPIRICAL ISSUES

The discussion in this section will focus on the practical question of what values are relevant for public policy. We argue that separate measures of option and existence values may be of interest only to economists. In a policy context, the option value discussion has given economic credence to the fact that potential users of a resource can place a monetary value on the resource. The notion of existence value takes this argument one step further and includes people who will never use a resource among those who might place a monetary value on it. Policy makers may not be concerned with the names that economists place on the various components of value, nor do they necessarily desire a measurement of each component. Rather, policy makers hope that economists are able to develop consistent and usable definitions of value, and are able to provide relatively accurate estimates of total value relevant to a given change in a resource. Bishop (1984) has concluded that the relevant concept for applied policy research is generally option price. The equivalent concept in the deterministic case is total value as defined in equation (3.7). That is, β_{TV} is just a special case of option price when the world is deterministic.

Using the simple model with only a single use argument, β_{op_s} will equal β_a in equation (1.7) when the world is certain since $(1-\pi)$ will be unity. In the case of uncertainty, option price includes total value (the expected value of consumers surplus) as was shown in equations (1.6), (1.7) and (1.9).

Measurement of total value or option price leads to several empirical questions. The elk valuation example will illustrate. An accepted tool for measuring consumptive use values (hunting) is the travel cost method. The problem in the context of the current model is that consumptive users may also have existence motivations or may be nonconsumptive and indirect users. Weak complementarity does not apply to existence motivations so that indirect methods of valuation such as the travel cost method cannot be used to measure existence values. The only available method for estimating existence value is contingent valuation since weak complementarity is not a prerequisite to its application.[11/] Contingent valuation may also be the best tool available for measuring indirect use values, if these types of values can be measured at all. Although weak complementarity probably applies for qualitative changes in indirect use, the diverse nature of indirect uses makes it difficult to apply any indirect technique of valuation. Thus, the travel cost method is only appropriate for estimating consumptive use values, and perhaps nonconsumptive use values in some cases.

One approach to this problem would be to use the travel cost method to estimate consumptive use values and nonconsumptive use values where

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11/ The use of contingent valuation to measure existence values for individuals who are users of a resource and have existence motivations for the resource would be limited due to the previously mentioned problem of precisely identifying existence value for a person with this type of preference structure.

that the payment card method and dichotomous choices may be superior to bidding games. Our research leads us to conclude that contingent valuation, although imperfect, is a reasonable tool for measuring the values that people place on consumptive and nonconsumptive uses of environmental assets. Whether this conclusion can be extended to contingent valuation measures of indirect use values, existence values and option values remains to be **seen.**[12/]

IV. PRELIMINARY RESULTS PROM AN APPLICATION

In a recent contingent valuation experiment we estimated the value of preserving two endangered species of wildlife in Wisconsin (bald eagles and striped **shiners).**[13/] The objective of this study was to test whether there are significant values that are not derived from direct contact with these wildlife resources. To facilitate this test, three types of values were estimated: a total value for bald eagles (BETV), a conditional total value for bald eagles $(BETV|_{e_2=0})$, and a total value for striped shiners (SSEV). Striped shiner total value is existence value as there is not any current or anticipated use associated with these fish in Wisconsin.

12/ There have been some studies where attempts have been made to use contingent valuation to estimate existence values (Brookshire, Eubanks and Randall, 1983; and Walsh, Loomis and Gillman, 1984). These studies appear to suffer from the vague definition of the term existence value, as was discussed in earlier sections of the present paper.

13/ The bald eagle is classified as a federally threatened species. The striped shiner is a minnow whose primary habitat is in sections of the Milwaukee River and it is not classified as a federally threatened or endangered species.

The values to be estimated are defined in a manner similar to the definitions developed in section II. The definitions are

$$V(P_e,P_z,\bar{\omega},\bar{\rho},I\text{-BETV}) = V(P_e^m,P_z,0,\bar{\rho},I) \tag{4.1}$$

$$V(P_{e_2}^m,P_{e_3},P_z,\bar{\omega},\bar{\rho},I\text{-BETV}|_{e_2=o}) = V(P_e^m,P_z,0,\bar{\rho},I) \tag{4.2}$$

$$V(P_e,P_z,\bar{\omega},\bar{\rho},I\text{-SSEV}) = V(P_e,P_z,\bar{\omega},0,I) \tag{4.3}$$

where $\mathbf{P_e}$ is a vector of market prices for the bald eagle use arguments, $\bar{\omega}$ is the current population of bald eagles, $\bar{\rho}$ is the current population of striped shiners, $\mathbf{e_2}$ and $\mathbf{e_3}$ are nonconsumptive and indirect use arguments for bald eagles, and all other arguments are as previously defined. There is not a consumptive use argument for bald eagles $(\mathbf{e_1})$ due to their status as an endangered species.

SURVEY PROCEDURES

The valuation questions for the present study were at the end of a mail survey conducted by the Wisconsin Department of Natural Resources (DNR). The purpose of the DNR's survey was to determine why Wisconsin residents do or do not contribute to the State's Endangered Resources Donation (ERD) program. Questionnaires were mailed to samples of individuals from three groups of Wisconsin residents: (1) identified environmentalists who attended selected DNR public meetings in 1984, (2) contributors to the ERD program in 1984, and (3) noncontributors to the ERD program in 1984. These sample groups will be referred to as Sample 1, Sample 2 and Sample 3, respectively.

One half of the individuals in each sample were asked a bald eagle total value question (BETV) and the other half were asked a conditional bald eagle total value question $(BETV|_{e_2=0})$. All respondents were administered the striped shiner total value question.[14/] The payment vehicle for eliciting these valuation responses was a membership to a private foundation that would conduct the necessary activities to preserve the species in question. This is similar to the payment vehicle used by Stoll and Johnson (1984) in their study of whooping cranes at the Aransas National Wildlife Refuge in Texas.

Two techniques were used to ask each valuation question. All respondents were administered both question formats. The first question format was the dichotomous choice technique which has been used in several contingent valuation studies (Bishop, Heberlein and Kealy 1983; Boyle and Bishop 1984; and Sellar, Chavas and Stoll 1983). Respondents were asked to accept or reject fixed membership fees to the foundation to preserve the species in question. Offers were even dollar amounts that were randomly selected within fixed intervals on the range \$1 to \$100. The second technique was a type of open-ended question. After respondents answered the dichotomous choice question they were asked what the most was that they would actually pay. Copies of the valuation questions are presented in Appendix A.

14/ Given the finding of Randall, Hoehn and Tolley that contingent values for an item may vary depending on the placement of the respective valuation question in the valuation process, it would have been desirable to alternate the order of the valuation questions in the questionnaires. This was not possible due to certain research limitations. In turn, the striped shiner valuation question was preceded by a bald eagle valuation question in all questionnaires. It should be noted that there was not a statistical difference between the striped shiner values that were preceded by a bald eagle total value question and the striped shiner values that were preceded by a conditional bald eagle total value question. Even so, this result would not address the issue of whether respondents bid most of their allotment for endangered species on bald eagles.

SURVEY RESULTS

A total of 1,162 questionnaires were mailed to individuals in the sample. Five hundred questionnaires were mailed to individuals in Sample 2 and an additional 500 were mailed to individuals in Sample 3. The remaining 162 questionnaires were sent to individuals in Sample 1. The overall response rate was 81 percent. The within group response rates were 85 percent for Sample 1, 89 percent for Sample 2, and 72 percent for Sample 3.

VALUE ESTIMATES

Bald eagle values were split according to whether respondents were viewers or nonviewers of bald eagles. This split was made on the basis of whether respondents had ever made a trip where one of their intentions was to view bald eagles. The information to make this classification was collected as part of the survey. An example of this question is also presented in Appendix A.

Open-Ended Results

Values estimated with the open-ended question are presented in Table 1. The estimated means show some obvious patterns when one looks across the rows and down the columns. An interesting result is that all of the estimated means are significantly different from zero, even the striped shiner existence value for Sample 3.

We hypothesized that BETV would equal $\mathbf{BETV}|_{e_2=o}$ for nonviewers. This null hypothesis could not be rejected for any of the three samples. On the other hand, if there are significant values associated with viewing bald eagles, then BETV would be significantly larger than $\mathbf{BETV}|_{2=o}$ for viewers. The null

TABLE 1. OPEN-ENDED VALUE ESTIMATES

Type of Value	Sample 1		Sample 2		Sample 3	
	Mean	Median	Mean	Median	Mean	Median
BETV - Viewer	**40.58 (5.92)**[a]	**24.95 (45)**[b]	31.39 (3.55)	20.25 90	27.65 (5.74)	15.25 31
- Nonviewer	25.27 (6.17)	24.63 15	20.42 (1.81)	15.05 (105)	12.47 (1.32)	9.85 (110)
$BETV\|_{e_2=o}$ -Viewer	44.25 (11.57)	24.60 44	28.25 (3.36)	20.20 75	21.38 (4.02)	15.60 34
- Nonviewer	21.06 (3.99)	15.25 18	21.93 (2.14)	10.43 (117)	12.62 (1.83)	5.19 91
SSEV	13.24 (1.45)	9.71 106	7.68 (0.65)	3.40 (340)	4.70 (0.71)	0.31 (255)

a/ Standard errors are presented in parentheses below the means.

b/ Sample sizes are presented in parentheses below the medians.

hypothesis that these two means are the same could not be rejected for each of the three samples of viewers.

There are several reasons why this last hypothesis test resulted in a conclusion which is contrary to expectations. Values associated with viewing bald eagles could be very small with respect to indirect and existence values. This may be plausible due to the bald eagles status as a symbol of freedom and patriotism. Alternatively, individuals could have provided their total values for bald eagles, or maybe even endangered species, regardless of the manner in which the valuation question was asked. This could be due to a survey problem in the questionnaire or it could be that individuals are not readily able to provide estimates of component values. This is an issue that was discussed by

Randall, Hoehn and Tolley (1981). There is no way to identify which explanation is true in the present research. It should be noted, however, that this result is reversed for two of the samples when the dichotomous choice results are examined. We suggest that future research to test this type of hypothesis be conducted with a resource that is not associated with the symbolism that is attached to bald eagles.

An issue of concern to us was whether the fixed offers in the dichotomous choice question influenced respondents answers to the open-ended question. The survey design allowed a simple test that was used by Boyle, Bishop and Welsh (1985) to test for starting point bias in bidding games. The statistical results of this test are presented in Appendix B. The findings indicate that eight of the open-ended means were influenced by the fixed offers in the dichotomous choice question. Thus, this effect must be considered when interpreting the open-ended valuation estimates presented in Table 1.

Dichotomous Choice Results

The dichotomous choice means are not simple averages, but rather, are computed from estimated logit models.[15/] The general form of the logit models estimated for the present study is

$$\pi = (1 + \exp(-\Theta Y))^{-1} \quad 5.1$$

15/ The means reported in Table 3 are computed by truncating the range of integration of the estimated logit models. This is a procedure that has been used in several contingent valuation studies to cope with the large tails that can occur with estimated logit models (Bishop, Heberlein and Kealy 1983; Boyle and Bishop 1984; and Sellar, Chavas and Stoll 1983). A simple rule of thumb discussed by Boyle and Bishop (1984) was used to choose the point of truncation. This is, the range of integration was truncated at the ninetieth percentile or the highest offer in the sample ($100 here), whichever was larger. The truncated models were normalized so that the areas under the p.d.f.'s equaled one.

where π is the probability of a yes response to the fixed offer, Θ is a vector of coefficients and Y is a vector of explanatory variables. The ΘY term takes the following form

$$\Theta Y = \Theta_0 + \Theta_1 \ln(\text{offer}) + \Theta_2 D_v \quad (5.2)$$

where D_v is a dummy variable that is equal to one when a respondent is classified as a viewer of eagles. Of course, the dummy variable for viewing does not enter the striped shiner equations.

The specification of equation (5.2) is not consistent with any conventional utility theoretic framework, as has been discussed by Hanemann (1984b). This conflict is due to the fact that income does not enter the functional specification. On the other hand, empirical applications have shown that specifications like equation (5.2) provide the best statistical fit to the data and that income is often not a significant explanatory variable (Bishop, Heberlein and Kealy 1983; and Boyle and Bishop 1984). This conclusion seems to be supported in the present study in that the specification in equation (5.3) fit the data better than a linear specification that is consistent with a conventional utility framework.[16/]

The estimated logit equations are presented in Table 2. Only equation (a) in Table 2 did not provide acceptable statistical results. The problem is that the coefficient Θ_0 is not significant. It is not plausible to assume that equation (a) would not have a constant term in the exponent. That is, a

16/ Specifications of the logit models with income as an argument were not possible since the DNR choose not to ask respondents to report their incomes on the questionnaires. We are currently trying to obtain secondary data on income since the sample for the study was drawn from Wisconsin Department of Revenue taxpayer records.

TABLE 2. ESTIMATED LOGIT COEFFICIENTS

Equation			Θ_o	Θ_1	Θ_2	χ^2 Statistic	N
(a)	BETV	- Sample 1	1.410 (1.151)[a/]	-0.642** (0.319)	1.212** (0.603)	8.84++[c/]	68
(b)		- Sample 2	2.234*[b/] (0.567)	-0.903* (0.173)	0.687** (0.302)	39.52+	222
(c)		- Sample 3	1.667* (0.584)	-0.978* (0.190)	1.019** (0.444)	39.22+	182
(d)	BETV$\|e_2$=o	- Sample 1	3.649* (1.222)	-1.124* (0.346)	--	14.10+	70
(e)		- Sample 2	2.991* (0.635)	-1.008* (0.183)	--	41.91+	216
(f)		- Sample 3	2.062* (0.729)	-1.134* (0.236)	1.137** (0.444)	33.22+	176
(g)	SSEV	- Sample 1	2.789* (0.672)	-1.269* (0.243)	--	39.32+	136
(h)		- Sample 2	--	-0.613* (0.049)	--	245.36+	435
(i)		- Sample 3	--	-0.833* (0.073)	--	274.54+	355

a/ Numbers in parentheses are asymptotic standard errors.

b/ Single asterisk denotes significance at the 1% level and double asterisk denotes significance at the 5% level.

c/ Single plus sign denotes significance at the 1% level and double plus sign denotes significance at the 5% level.

specification without a constant term in the exponent would imply that the median response for nonviewers is $1. That would not be a reasonable result. Given that Θ_o is not significant in equation (a), the viewer and nonviewer values computed from this equation should be cautiously interpreted. However, it is plausible that Θ_0 is not significant in equations (h) and (i). It does appear reasonable that the striped shiner medians might be only $1 for Samples 2 and 3.

An interesting result is that there was not a significant difference between the way viewers and nonviewers responded to the conditional bald eagle total value question for Samples 1 and 2. The β_2 coefficient was not significant in either of these equations [equations (d) and e)]. This is in contrast to the open-ended result which indicated that there was a significant difference between viewer and nonviewer conditional bald eagle total values in each group. The dichotomous choice results were in agreement with the open-ended results when this same comparison was made for Sample 3.

The estimated values are presented in Table 3. As in Table 1, the means show some obvious patterns when one looks across the rows and down the columns.

A Comparison of Results

There are five open-ended means that could not be directly compared with the dichotomous choice means. The bald eagle total value for nonviewers in Sample 1 could not be tested due to a small sample size, i.e., the central limit theorem does not apply. The other four open-ended means for which direct comparisons could not be made are the conditional bald eagle total values for Samples 1 and 2. This is because the dichotomous choice means are the same for viewers and nonviewers, and the open-ended estimates are statistically

TABLE 3. DICHOTOMOUS CHOICE VALUE ESTIMATES

Type of Value	Sample 1		Sample 2		Sample 3	
	Mean	Median	Mean	Median	Mean	Median
BETV - Viewer	181.43	59.54[b/]	43.93	25.40	24.36	15.59
- Nonviewer	27.16	9.00	20.23	11.88	11.24	5.50
BETV$\|e_2=o$ - Viewer	35.51	25.70	29.56	19.44	22.87	16.79
- Nonviewer	35.51	25.70	29.56	19.44	11.47	6.16
SSEV	14.38	9.01	5.67	1.00	4.17	1.00

a/ Significance of the estimates is tested by testing the significance of the estimated logit equations. See TABLE 2 for these results.

b/ It is stated in footnote (15) that the means were derived by truncating the range of integration and normalizing the logit models so that the areas under the p.d.f.'s would be one. The reported medians are for the untruncated models. The medians from the untruncated models are presented because a median is not sensitive to the mass in the tail of a distribution.

different for viewers and nonviewers. In this context, the dichotomous choice means for Samples 1 and 2 are not significantly different from the associated open-ended means for viewers.

Treating the dichotomous choice means as parameters, and invoking the central limit theorem, it is possible to test whether the means derived from the two valuation techniques are statistically the same for cases where direct comparisons can be made. There are ten pairs of means where a direct comparison can be made. In seven of these cases there is not a statistical difference. The cases where a statistical difference occurs are bald eagle total values for viewers in Samples 1 and 2, and striped shiner existence value for Sample 2. The difference for Sample 1 is not surprising given the statistical problems with the logit equation from which the dichotomous choice means were derived.

Finally, as was previously noted, the bald eagle total values and conditional total values are not significantly different for viewers in the open-ended data, whereas the dichotomous choice results indicate that bald eagle viewer total values and conditional total values are significantly different in Samples 1 and 2. The dichotomous choice results do support the open-ended results for Sample 3 with respect to this comparison, i.e., equations (c) and (f) are not significantly different.

II. CONCLUSIONS

The valuation of nonmarketed natural resources is a complex conceptual and empirical problem, as this discussion of, and application to, the valuation of wildlife portrays. In this paper we attempted to clarify some of the conceptual issues and discussed some of the empirical questions relevant to the valuation nonmarketed resources. In particular, we pointed out that consumptive use of a resource is merely one category of use. There are also nonconsumptive and indirect users. Nonconsumptive use and indirect use are likely to be associated with resources that have relatively attractive aesthetic features.

We also proposed what we feel is an acceptable definition of existence value. Hanemann (1984a) has said that, "...it is tempting to characterize the burgeoning literature on option value as a label in search of contents." It may be more than tempting to make the same statement about the existence value literature. Nearly everyone would agree that some people who are sure they will never come in contact with a resource may still place a monetary value on it. The disagreement arises with respect to what constitutes and motivates such values. We have proposed in this paper that the existence value label be used to refer only to values that are motivated by altruism.

On the practical side, we do not believe that it is necessary or desirable to measure all of the individual components of total value. Economists are concerned with these various components to avoid gaps in the conceptual framework for valuation and to also avoid double counting. Estimates of components such as option value and existence value can then be used to verify the theoretical models that define such values. Measures of option value and existence value as separate entities are generally irrelevant for policy applications. Policy research generally requires estimates of the total value associated with an incremental change in a resource.

In the context of valuing wildlife resources, contingent valuation is the only tool available for measuring the total value. All other techniques of valuation (indirect methods) require on the notion of weak complementarity to measure qualitative changes in resources. These indirect methods of valuation are not appropriate for measuring existence values. In addition, indirect methods may not be operational for measuring indirect or nonconsumptive use values, although the concept of weak complementarity may apply. Sufficient research has been done to show that contingent valuation is a useful tool for measuring consumptive and nonconsumptive use values, but more research is needed regarding indirect use and existence values.

With respect to the empirical application we feel obliged to ask, can contingent values, such as the estimates presented in this paper, be taken as clear evidence that intrinsic values for wildlife species are positive? As was previously discussed, there is a growing body of research that is contributing to a greater confidence that contingent valuation produces _use_ values that are sufficiently accurate to be acceptable in policy analysis (Bishop _et al_. 1984). On the other hand, doubts have been voiced as to whether this conclusion extends to more esoteric concepts like existence value (Cummings, Brookshire and Schulze 1984). This is an issue that requires more research. However, we have previously concluded that altruistic motives leading to positive utility from the existence of a wildlife resource are quite compatible with economic theory. Furthermore, the present contingent valuation results indicate a substantial willingness to pay that is not associated with direct contact with both a well-known and an obscure species.

The bottom line is that we as economists must give careful consideration to the components of total value, and to the motivation for the components, before values are estimated. This is necessary to obtain accurate and appropriate estimates of value even when total value is the desired end result for public policy analysis. Smith (1984b) has stated that researchers should, "...ask individuals first how they use the resources involved and how they think about their values," before values are estimated. In addition, a thoughtful application of empirical techniques for measuring values is needed. Finally, the concepts discussed in this paper in the context of wildlife are applicable to other resources when the peculiarities of each resource is accounted for.

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APPENDIX A

INTRODUCTION TO VALUATION QUESTIONS

THIS LAST SERIES OF QUESTIONS INVOLVES FIGURING OUT
THE ECONOMIC VALUE OF ENDANGERED SPECIES

When it comes down to what people think is important, wildlife often has a hard time competing with other issues. We sometimes talk about things that are important to us in terms of their dollar value (such as how many dollars a building is worth) but it has been difficult to talk about what wildlife is worth in terms of dollars. Researchers at the University of Wisconsin are interested in these questions, and in cooperation with them, we are including this section in our questionnaire.

Please keep in mind that the questions involve pretend situations. Even so, you answers will still help us decide what amount of money should be spent for endangered species programs, and how the money should be spent. Please disregard your answers from the sections about the Endangered Resources Donation program while answering the questions in this section. We are interested in how much you personally value endangered species, no matter what you think of the Endangered Resources Donation program.

BALD EAGLE TOTAL VALUE QUESTIONS (BETV)

We would like you to pretend that all funding to preserve bald eagles in Wisconsin is terminated. Assume that without funding, there will not be an organized effort to preserve bald eagles in Wisconsin and bald eagles will become extinct in our state. Suppose that an independent private foundation is formed to preserve bald eagles in Wisconsin and to prevent the possibility of extinction. The activities of the foundation will include maintaining and restoring bald eagle habitats. Please assume that the foundation will be able to save the bald eagle.

Pretend that the foundation is to be funded by selling supporting memberships. All members will be provided with information, at no cost, on how to conveniently view bald eagles in Wisconsin. Members who do not wish to view eagles will have the satisfaction of knowing that they helped preserve the bald eagle in Wisconsin. These people may have various resons for wanting to preserve bald eagles. Some of these reasons might be: a gift to future generations, a sense of responsibility for the environment, sympathy for animals, and generosity towards friends and relatives.

If a supporting membership cost $ per year, would you become a member and help to make sure that bald eagles will not become extinct in Wisconsin?

___ yes -- I would become a supporting member at this amount. In fact, I would even pay up to $______ per year for a membership.
(WRITE IN THE HIGHEST DOLLAR AMOUNT THAT YOU WOULD PAY.)

___ no -- I would not become a supporting member at this amount.

IF NOT: WHY NOT? (CHECK ALL THAT APPLY)

___ The membership costs too much, but I would pay $______per year.
(WRITE IN THE HIGHEST DOLLAR AMOUNT THAT YOU WOULD PAY.)

___ I would like to see the bald eagle preserved in Wisconsin, but I would let others pay for preservation.

___ The bald eagle is not worth anything to me.

___ I refuse to place a dollar value on bald eagles.

___ I object to the way the question was asked.

___ I felt that I didn't have enough information to answer yes.

___ Other, please explain ____

____

BALD EAGLE CONDITIONAL TOTAL VALUE QUESTION $(\mathbf{BETV}|_{e_2=0})$

We would dike you to pretend that all funding to preserve bald eagles in Wisconsin is terminated. Assume that without funding, there will not be an organized effort to preserve bald eagles in Wisconsin and bald eagles will become extinct in our state. Suppose that an independent private foundation is formed to preserve bald eagles in Wisconsin and to prevent the possibility of extinction. The activities of the foundation will include maintaining and restoring bald eagle habitats. Please assume that the foundation will be able to save the bald eagle.

Pretend that the foundation is to be funded by selling supporting memberships. However, bald eagles will be located in remote areas of Wisconsin so that it will be extremely unlikely that you will ever see a bald eagle in the wild in Wisconsin. Under these conditions, members of the foundation will still have the satisfaction of knowing that they are helping to preserve the bald eagle in Wisconsin. These people may have various reasons for wanting to preserve bald eagles. Some of these reasons might be: a gift to future generations, a sense of responsibility for the environment, sympathy for animals, and generosity towards friends and relatives.

If a supporting membership cost $ per year, would you become a member and help to make sure that bald eagles will not become extinct in Wisconsin?

___ yes -- I would become a supporting member at this amount. In fact, I would even pay up to $_____ per year for a membership. (WRITE IN THE HIGHEST DOLLAR AMOUNT THAT YOU WOULD PAY.)

___ no -- I would not become a supporting member at this amount.

IF NOT: WHY NOT? (CHECK ALL THAT APPLY)

___ The membership costs too much, but I would pay $_____ per year. (WRITE IN THE HIGHEST DOLLAR AMOUNT THAT YOU WOULD PAY.)

___ I would like to see the bald eagle preserved in Wisconsin, but I would let others pay for preservation.

___ The bald eagle is not worth anything to me.

___ I refuse to place a dollar value on bald eagles.

___ I object to the way the question was asked.

___ I felt that I didn't have enough information to answer yes.

___ Other, please explain ____

____

STRIPED SHINER EXISTENCE VALUE QUESTION (SSEV)

Now we would like you to assume that there is enough funding to preserve the bald eagle in Wisconsin. That is, it will not be necessary to form a bald eagle foundation and to ask for donations from the public. In the next few questions, we are interested in finding out about the dollar value you place on another one of Wisconsin's endangered species.

We would now like you to pretend that all funding to preserve the striped shiner in Wisconsin is terminated. The striped shiner is an endangered species of fish in Wisconsin that most Wisconsin residents will never see. Assume that without funding to maintain habitat, the striped shiner will become extinct in Wisconsin. Suppose that another independent private foundation is formed to preserve striped shiners in Wisconsin. The objectives of the foundation will be to recover and maintain striped shiner habitat in Wisconsin. Please assume that this foundation will be able to save the striped shiner.

Pretend that the striped shiner foundation is to be funded by selling supporting memberships. It is highly unlikely that members of the foundation will ever see a striped shiner in the wild. Even so, people may choose to become members for various reasons such as a gift to future generations, a sense of responsibility for the environment, sympathy for animals, and generosity toward friends and relatives.

If a supporting membership in the striped shiner foundation cost $ per year, would you become a member and help to make sure that striped shiners will not become extinct in Wisconsin?

___ yes -- I would become a supporting member at this amount. In fact I would even pay up to $_____ per year for a membership. (WRITE IN THE HIGHEST DOLLAR AMOUNT THAT YOU WOULD PAY.)

___ no -- I would not become a supporting member.

IF NO: WHY NOT? (CHECK ALL THAT APPLY)

___ The membership costs too much, but I would pay $_____ per year. (WRITE IN THE HIGHEST DOLLAR AMOUNT THAT YOU WOULD PAY.)

___ I would like to see the striped shiner preserved in Wisconsin, but I would let others pay for preservation.

___ The striped shiner is not worth anything to me.

___ I refuse to place a dollar value on striped shiners.

___ I object to the way the question was asked.

___ I felt that I didn't have enough information to answer yes.

___ Other, please explain ____

____

BALD EAGLE VIEWING QUESTION

Do you ever take trips where one of your <u>intentions</u> is to try to see a bald eagle?

___ regularly

___ sometimes

___ once

___ never have, but would like to

___ never will

APPENDIX B

ESTIMATED COEFFICIENTS FOR OFFER EFFECT EQUATIONS

	Equation[a]	α_0	α_1	N
(1)	BETV - Sample 1 - Viewer	21.277**[b] (9.423)[c]	0.547** (0.217)	45
(2)	- Nonviewer	14.152 (11.852)	0.260 (0.237)	15
(3)	- Sample 2 - Viewer	11.495** (5.588)	0.546* (0.125)	90
(4)	- Nonviewer	11.637* (2.725)	0.263* (0.064)	105
(5)	- Sample 3 - Viewer	8.515 (9.154)	0.568** (0.222)	31
(6)	- Nonviewer	3.748* (0.614)	-0.020 (0.048)	110
(7)	$BETV \mid e_2=o$ - Sample 1 - Viewer	10.269*** (5.543)	-0.436 (0.844)	44
(8)	- Nonviewer	21.851* (6.851)	-0.015 (0.153)	19
(9)	- Sample 2 - Viewer	21.715* (6.009)	0.156 (0.119)	75
(10)	- Nonviewer	10.153* (3.384)	0.309* (0.072)	117
(11)	- Sample 3 - Viewer	7.153* (2.020)	-0.525 (0.328)	34
(12)	- Nonviewer	9.604* (3.245)	0.086 (0.077)	91

ESTIMATED COEFFICIENTS FOR OFFER EFFECT EQUATIONS (CONT.)

Equation[a/]		α_0	α_1	N
(13) SSEV	- Sample 1	9.519*	0.158**	106
		(2.179)	(0.070)	
14	- Sample 2	5.445*	0.084*	340
		(1.009)	(0.029)	
15	- Sample 3	1.929***	0.106*	255
		(1.082)	(0.032)	

a/ The equations have the following functional form:

$$\text{(open-ended bid)} = \alpha_0 + \alpha_1\text{(offer)}.$$

The estimated equations have been corrected for heteroskedasticity if it was identified as a problem.

b/ Single asterisk denotes significance at the 99% level, double asterisk denotes significance at the 95% level and triple asterisk denotes significance at the 90% level.

c/ Numbers in parentheses are standard errors.

DRAFT

Exploring Existence Value

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This paper explores the role of existence value in benefit-cost analysis of policies involving natural and environmental resources. Existence value is one of several components of benefits, including option value and quasi-option value, which may accrue to people who do not necessarily visit the resources. We tend to assume that with the inclusion of intrinsic benefits, benefit-cost analysis Will be more resource-conserving, though this assumption is being eroded by ambiguous results on option and quasi-option value. Regardless of whether the inclusion of intrinsic benefits makes benefit-cost analysis more resource conserving, it makes the analysis less erroneous. There is no guarantee that the development of partial measurers of benefits and costs will provide even a potential improvement of the allocation of resources.

There are at least two perspectives on the development and use of existence value. The simplest is to view such work as part of the continuing evolution of benefit-cost analysis to include "intangibles," those benefits which are especially difficult to measure. In the analysis of projects, rules and regulations, we tend to focus our tools on those activities which by our prior notions are important but are also measureable. When we grapple with the practical aspect of including existence value in benefit cost analysis, we are making estimates of benefit more inclusive, and in an incremental way, improving the tool. Viewed in this way, work on existence value is simply another of the many positive developments which gradually improve benefit-cost analysis and possibly the allocation of resources.

There is a second and more disturbing perspective on attempts to measure non-use values such as existence value. In the analysis below we will give a more precise definition of existence value, but for the moment, let us simply define it as an individual's willingness to pay for a change (or to avoid a change) in the provision of a resource with no prospects or no intention of enjoying in situ services from the resource. This definition of value is quite elastic and is naturally appealling to those who wish that economics could be more holistic. In this aspect of existence value we find both its promise and its danger. It allows us the temerity of believing that we can do benefit-cost analysis, not of individual projects, but of the economic order. For those of us educated in an era when questions about the economic order were important, existence value and related concepts offer a larger vision of economics than the one that the practical exigencies of benefit-cost analysis force us to adopt. But here lies the danger. For if we utilize the elasticity of these concepts in attempting to measure everything, we will most certainly fail, and we may in the process undermine whatever faith is placed in things we do well.

These ruminations about existence value are meant to motivate the paper. Because of its potential, and because it is less susceptible to disproof than in other sources of benefits, existence value should be subjected to careful and thorough discussions of concept and substance. When dealing with existence value more than other sources of value, we need to concern ourselves with the question "what are we measuring" rather than "what is the measurement?"

Many of us find ourselves working on problems addressed by John Krutilla in the elegant essay "Conservation Reconsidered." Thus it is no surprise that this essay is the source of a fairly complete exposition of existence value. First Krutilla recognized that "There are many persons who obtain satisfaction from mere knowledge that part of wilderness North America remains even though they would be appalled by the prospect of being exposed to it" (p. 781). Then he argued that market outcomes are inefficient for resources which provide existence value, because this value is surely a nondepletable service flow which cannot be appropriated. Hence, efficient allocation of natural resources which provide existence value requires that this value be added to the value of other service flows to calculate the total benefits of preserving natural resources.

Empirical evidence of existence value has been of two sorts. First we have indirect evidence based on people's willingness to join organizations Such as the Sierra Club, Aububon Society, etc., organizations which are active in resource conservation. This sort of activity, not always based on use, seems to be an under-utilized source of revealed preferences implying existence value. Second, most of the more formal enquiries, using contingent valuation, are ably summarized by Fisher and Raucher. They give evidence that intrinsic benefits (which include option value as well as existence value) tend to be some fraction of the use value of resource changes. Other research, for example Walsh, Sanders and Loomis and Schulze et al. gives evidence that existence value is greater than use value, in the Schulze et al. case, substantially greater.

The thrust of this review suggests that economists have accepted existence value as a reasonable concept, and are now intent on applying contingent valuation approaches to measuring existence value.

Conceptual discussions of existence value have focused on basically three issues:

1) Should existence value apply to all but on-site "hands-on" uses of the resource, or is it limited only to service flows which are not connected with <u>any</u> other resource use?

2) Does the measurement of the resource from which existence value is derived matter?

3) Do the motives which give rise to existence value matter?

4) Is existence value limited to natural resources, i.e. the "biological and geomorphological variety" of which Krutilla speaks?

Some futher discussion of these issues will help in developing our understanding of the proper role of existence value in benefit-cost analysis.

The purpose of this paper is to explore the concept of existence value in some detail. The first section repeats for convenience a fairly well known definition of existence value. Section 2 will explore the implications of different definitions. Section 3 will argue that motives matter and that existence value need not be limited to any single type of good. Section 4 will provide some preliminary empirical evidence. on the issue of motives and their implications,

1. The Accounting Definition of Existence Value

Before we discuss the breadth of the concept of existence value, it will be useful to repeat the definition of this value as derived from the minimum cost or expenditure function. We proceed in a framework of certainty. Details about the following summary can be found in McConnell, Smith or Smith, Desvousges, and Freeman, ch. 6. Let the preference function be U(x,R) where x is an n-dimensional vector of commodities purchased at the price vector p, and R is the resource whose existence may be valued. The minimal cost of obtaining utility level u is given by the standard cost function

$$C(p,R,u) = \min_{x}[x \cdot p | U(x,R) = u] \qquad (1)$$

To define existence value, let x be partitioned such that $x = (x^*, x^o)$ where x^* is a vector of commodities complementary to R. For example, for $x^* = (x_1, x_2)$ x_1 could be visits to the resource and x_2 purchases of a magazine which features news about the resource. Let p^* be the price vector which sets the Hicksian demands for x^* to zero.[1] Then the existence value (EV) of a change in the resource from R_1 to R_2 is the change in the cost of obtaining utility u at prices p^*.

$$EV = C(p^*, R_1, u) - C(p^*, R_2, u) \qquad (2)$$

The change in use value from the change in the resource is the sum of the change in the areas under the Hicksian demand curves for x^* at the appropriately defined limit prices. At R_1, the sum of the areas under the Hicksian demand curves, is given by $C(p^*,R_1,u) - C(p,R_1,u)$. The change in this value, which we call UV for use value, is given by

$$UV = C(p^*,R_2,u) - C(p,R_2,u) - \{C(p^*,R_1,u) - C(p,R_1,u)\} \quad (3)$$

By adding existence and use value we obtain the accounting identity that total value equals use value plus existence value:[2]

$$TV = C(p,R_1,u) - C(p,R_2,u) = EV + UV \quad (4)$$

We can use these definitions as we discuss various issues in defining and measuring existence value.

2. Issues in Defining Existence Value

The first issue concerns the precise definition of existence value. At one extreme is the notion that any complementarity with the resource and market commodities connotes use. For example, when one reads a magazine article about Yellowstone, then one is gaining use value from the resource. This view of existence value is found in Randall and Stoll. The other perspective, see for example Smith, would equate existence value to any use of the resource which does not utilize *in situ* services. One may also find this view in Krutilla and Fisher (p. 124).

What difference does it make whether we define existence value as any offsite enjoyment of the resource service flows, or require it to be enjoyment of the resource not complementary to any marketed good? Aside from some technical issues relating to the cost and utility function the answer is part pragmatic and part substantive. The pragmatic part concerns measurement. If we define existence value in its *most broad sense*, then we hold out the hope that we can measure at least part of the existence value from a resource change as changes in the areas under the demand curves for commodities not connected with *in situ* use. For example, we measure the existence value of the California condor by estimating the demand for books and articles about the condor and show how these demands change with the change in the stock of condors. The resolution of this issue is partly pragmatic. If in fact one is able to estimate the demand for a good which is weakly. Complementary to the resource, then it may be argued that we can use these links to estimate the existence value. In effect, we replace the violation of weak complementarity between onsite use and the resource with weak complementarity between the resource and several offsite goods. In the process, one must be careful of aggregating benefits across several goods.[3] It seems most unlikely that one will be able to estimate via the behavior-based techniques the individual values associated with a change in the resource.[4]

Whether we should limit definitions of the use of the resource relates to the number of elements in x^*, the complementary vector. We assume that x^*_1 is onsite use, and the rest of the x^*'s are offsite uses. Let p_1^* be the price that sets the Hicksian demand for x_1 to zero. Then total existence value (TEV) is the change in cost of obtaining utility u at the price vector $(p_1^*, p_2, \ldots p_n)$:

$$TEV = C(p_1^*, p_2, \ldots p_n, R_1, u) - C(p_1^*, p_2, \ldots p_n, R_2, u) \quad (5)$$

This expression equates existence value with any offsite use, and the principal rationale for this is pragmatic. This definition mixes values from uses such as reading magazines about a natural resource with values derived from the altruistic motive of enjoying the pleasure of others who visit the site (and the pleasure of others who read magazine articles about the resource?).

In concept, this broad definition causes no difficulty. It is merely an accounting change, reclassifying benefits from use to existence in expression (4). By manipulating the cost function, we can show that the total value of a resource change is

$$TV = TEV + (\text{Change in area under Hicksian demand for } x_1) \qquad (6)$$

If there is only one use complementary to R_1, then $x_1 = x^*$, and there is no difference between the two definitions, If we wish to ignore motives, then we can lump all offsite uses into one category, call their value total existence value, and add them to the change in onsite value for an accounting of total value. If motives don't matter, and we feel confident that we can measure these offsites uses and existence value together, then we may as well lump them all together. If we wish to maintain some notion of existence value that is not connected with any other commodity, or if we are perhaps interested in motives which induce such value, then we would have to add up areas under the Hicksian demand curve for each element in x*.

The substantive aspect of the definition of existence value leads us to a consideration of the question of motives. Suppose we take the narrow view, that existence value is not connected with any other commodity. We will call this "pure existence value". Defined in this way, pure existence value exerts no influence on behavior, and we are led to ask "Why do people value resources which they cannot enjoy directly or indirectly?" A plausible explanation is altruism. We may value the existence of resources because they are valued by others of our own generation or by future generations. Randall and Stoll further argue that we can distinguish among various kinds of altruism.

These conceptual discussions of existence values have led economists into the unfamiliar territory of motives. As Smith, Desvousges and Freeman observe, "This discussion of the possible motivations for pure existence value is inconclusive... Definitions can be considered in part as a matter of taste. A set of definitions can be considered useful if it furthers the research objective and leads to useful answers to meaningful questions and if the definitions are based on operationally meaningful distinctions" (pp. 6-6 to 6-7). We agree in general with these comments, but will argue for operationally meaningful distinctions in section 3 below.

A second issue worth exploring is the nature of the resource, R. Typically R has been treated as if it only influences behavior as an argument in the preference function. The recent work by Smith and by Smith, Desvousges, and Freeman investigates the question of welfare measurement for changes in R when R acts as an implicit constraint.[5] We find many different measures of R, even in the context of measuring existence value. For example, it can be an index of visibility (Schultze et al.), grizzly bears and bighorn sheep (Brookshire et al.), an index of water quality (Desvousges, Smith and McGivney) or the availability of wild and scenic rivers (Walsh et al.). But there are two different ways of looking at measures of resources in the context of discussions of weak complementarity and existence value. Both views may be useful in understanding the nature of a resource change, but the distinction of views appears to make little difference to the measurement of welfare. To maintain some simplicity in the following arguments, we assume that R is weakly complementary to x_1 only, and that there are no offsite uses. Hence, when x_1 is zero, the only benefit from a change in R is existence value.

First, we can conceive of R as simply an index of quality, as it is most frequently used. In that case R simply enters the preference function, and is not part of any explicit or implicit production process. It merely enhances the enjoyment of use. Second R can be viewed as derived from the production process. In such a case we might think of minimum levels of R as being essential for x_1. This view of R in the preference function makes the link between x_1 and R a technical link. Denote the critical minimum level of R as R_m, the level of the resource which reduces use to zero, and suppose that R_0 is less than R_m. We are interested in changes in welfare induced by increasing the resource from its minimum level at R_0 to some level R_1. This approach is similar in spirit to work by Smith and by Smith, Desvousges and Freeman. In effect, we introduce a kind of symmetry in the preference function. Weak complementary would give

$$\partial U(0, x_2,\ldots x_n,R)/\partial R = 0$$

while having R at R_o implies

$$x_1 = x_1(p,R_o)$$
$$= 0 \quad .$$

or

$$U(x,R) = U(0,x_2,\ldots x_n,R_o).$$

The symmetry, perhaps not apparent, exists because when R is below some critical minimum Ro, changes in x_1 bring no net increases in utility. That is, when R = R_o,

$$\partial U(x,R_o)/\partial x_1 = 0 \tag{7}$$

This symmetry also extends to the expenditure function. The classic result of Mäler concerning weak complementarity simply states that when the price vector reaches p*, the expenditure function is stable with regard to the resource level. Specifying R as an implicit but essential input gives us another condition in the absence of existence value. For resource levels less than R_m, changes in the price of x_1 have no impact on the expenditure function.

$$C(p_1^o,p_2\ldots p_n,R_o,u) - C(p,R_o,u) = 0$$

when there is no existence value, broadly defined. Goes this additional link between R and x_1 provide any additional information? It suggests looking for existence value in two ways. First, when individuals don't use a resource because they are priced out, we can look for existence value. Second, when the resource level is so low that the technical link involves no direct use, existence motives, that is, care about the resource for reasons other than its direct use, will induce existence value:

$$EV = C(p,R_o,u) - C(p,R_1,u) \tag{8}$$

where R_0, R_1 are less than the critical minimum.

What is the practical significance of this distinction? It is clear from earlier discussion of existence value that changes in R influence the choke price for x_1, so that reductions in R can bring x_1 to zero without technical or implicit production links. That is, the p_1^* that satisfies $x_1(p_1^*) = 0$ depends on R, so that with enough reductions in R, and the right complementarity between R and x_1, p_1^* will fall. The case of the technical link differs. When the link between x_1 and R is purely technical, and R falls below the critical minimum or essential level, then no other levels of $(p_1 \ldots p_n)$ will induce a positive level of x_1 to be chosen. Thus, the technical link influences behavior independent of the utility function and the budget constraint.

An example can help illustrate the issues. Suppose utility is given by

$$U(x_1, x_2, R) = a\, x_1 + \ln x_2 + b \tag{9}$$

where a and b are functions of R such that $\partial a/\partial R > 0$, $\partial b/\partial R > 0$. Suppose that $a(R_m) = 0$, where R_m is the critical minimum level of the resource. This is a weakly complementary link. Thus, when $R = R_m$, $x_1 = 0$. The Hicksian demand for x_1 is given by

$$x_1 = [u - b - \ln(p_1/ap_2)]/a$$

and the Hicksian choke price is

$$p_1^* = a\, p_2 \exp(u - b) \tag{10}$$

Now from this example it is clear that we can adjust R two different ways to get x_1 to zero. First, from (9) we see that if $R = R_m$, $a = 0$ and x_1 will not be chosen regardless of p. This most closely resembles the elimination of a wilderness area or converting a beach to condominiums. Second, we can adjust R such that

$$p_1 > a(R)p_2\exp(\dot{u} - b(R))$$

and the user spends his money on something else, even though he could technically still enjoy the service of the site.

The important issue here is whether defining the resource as essential raises any special problems in establishing measures of use and existence value. To address this issue, we can imagine three kinds of policy changes, depending on whether the resource is greater than or less than the critical minimum. Let R_1 be the initial resource level and R_2 be the resource level after the implementation of a policy change. Then we have the following cases:

a) $R_1 < R_2 < R_m$

b) $R_1 < R_m < R_2$

c) $R_m < R_1 < R_2$

In case a, the policy induces only existence value, and in cases (b) and (c) the policy brings use and existence value. Consider case (b). We can always use the identity

$$\begin{aligned} TV &= C(p,R_1,u) - C(p,R_2,u) \\ &= C(p,R_1,u) - C(p,R_m,u) + C(p,R_m,u) - C(p,R_2,u) \end{aligned} \tag{11}$$

to define total value as in (4). The term $C(p,R_1,u) - C(p,R_m,u)$ is composed of existence value only, since the resource levels less than R_m will not allow use. The second term on the right hand side has both existence and use components, and can be decomposed as in (2) - (4) or with more detail, as in McConnell, pp. 259-261. Case c, when the resource is greater than the minimum level, is a special case of (11), without the first two terms, and hence presents no special problems.

An example decomposing the welfare changes for case b is instructive. For the preference function (9), the cost function is

$$C(p,R,u) = \begin{cases} p_2\exp(u - b) & \text{if } p_1 \geq p^*_1 \text{ or } R_m \geq R \\ (p_1/a)[u - b + 1/p_2 - \ln(p_1/ap_2)] & p_1 < p^*_1 \text{ and } R_m < R \end{cases}$$

where the dependence of C on R is through a and b: $a = a(R)$, $b = b(R)$ and $a'(R)$, $b'(R) > 0$. The value decomposed as in (11) is

$$C(p,R_1,u) - C(p,R_m,u) = p_2\exp(u)[\exp(-b(R_1) - \exp(-b(R_m))] \tag{12}$$

$$C(p,R_m,u) - C(p,R_2,u) = p_2\exp(u - b(R_m))$$

$$- \frac{p_1}{a(R_2)}[u - b(R_2) + \frac{1}{p_2} - \ln(\frac{p_1}{a(R_2)p_2})] \tag{13}$$

The sum of (12) and (13) is the total value of the resource change, as given by (11). Expression (12) is existence value, because use value is zero as long as $R < R_m$. Expression (13) is both use and existence value, but it too can be decomposed using the definitions of existence and use value in expressions (2) and (3). By (2), the existence value component of (13) is

$$C(p^*_1,p_2,R_m,u) - C(p^*_1,p_2,R_2,u) = p_2\exp(u)[\exp(-b(R_m)) - \exp(-b(R_2))] \tag{14}$$

The use value component of (13), based on the definition in (4), is the increase in use value (area under the Hicksian demand curve) created by a change from R_m to R_2. Since use value is zero at R_m(because x_1 is zero at R_m), this change is use value is simply the area under the Hicksian demand curve at R_2:

$$UV = C(p^*_1,p_2,R_2,u) - C(p,R_2,u)$$

$$= p_2\exp(u - b(R_2)) - \frac{p_1}{a(R_2)}[u - b(R_2) + \frac{1}{p_2} - \ln(\frac{p_1}{a(R_2)p_2})] \tag{15}$$

Expressions (15) and (14) add up to total value; as given in (13), so that in principal at least, the case where the resource is essential causes no difficulty in the decomposition of total value into use and existence value.

This discussion of decomposing use and existence value for a resource change has been based on the fact that when $R = R_m$; purchases of x_1 bring no utility and hence any positive level of x_1 is a waste of money. What about the case where R_m reduces x_1 to zero by a technical link, and not through the utility function? We will get the same answer as we have above. With $R \lessgtr R_m$, the expenditure function is independent of x_1, and the welfare analysis of changes in R measures existence value only. When the change is from R_1 to R_2 where $R_1 < R_m < R_2$ (case b), we can proceed as we have in the example above.

We can summarize this result with an other example. Suppose that R is the depth of water in a lake in feet. Let x_1 be swimming and $R_m = 3$; i.e., when the depth is less than three feet, swimming is impossible. Existence value is attached to R because greater R means greater biological diversity. A change in R from two feet to four feet can be decomposed as follows. We have the existence value of the change from two feet to three feet. We have the total value from three feet to four feet, which we can decompose into existence and use values.

Thus, while it is clearly possible that resource levels may constrain use just as the level of use may constrain enjoyment of the resource, accounting for this phenomenon with the expenditure function appears to present no special problems. This conclusion, however, presumes knowledge of the expenditure function and the critical minimum level of resource, a very optimistic presumption.

3. Do Motives Matter?

In previous sections, we flirted with a discussion of motives, but we have not argued that motives matter. Here we extend our enquiry to considering motives more carefully. Existence value, whether broadly or narrowly defined, cannot practically be linked to behavior, so that its estimation requires the use of contingent valuation methods. We suggest that it is necessary to consider what motives underlie existence value bids for proper design and interpretation of contingent valuation experiments.

Consider the following categories of the motives that may underlie pure existence value:

1) individualistic altruism - altruism in the sense that individuals gain value from the enhanced income or well being of others without regard to the manner in which the utility gains of others were achieved.

2) paternalistic altruism - altruism in the sense that individuals gain value from the use of a particular good or resource by others.[6]

3) all other motives.

Whether individualistic or paternalistic altruism (or neither) underlies preferences is an empirical question. At this point, our purpose is merely to suggest that both kinds of altruism are possible.

In general, individualistic altruism could be directed toward heirs (bequest value), or others of current or future generations. For simplicity, consider a 2-person world where person A is a nonuser and person B is a user of the publicly provided resource R.[7] Suppose that existence value accrues to person A from the provision of R. If the underlying motive is individualistic altruism, then we could envision persons A and B's preference functions as follows:

$$U^A = U^A(Y_A, U_B(Y_B, R)) \tag{16}$$

$$U^B = U^B(Y_B, R) \;, \tag{17}$$

where U^i and Y_i are the utility and income levels, respectively, for person i = A,B. A unit increase in R yields existence value to person A when $\frac{\partial U^A}{\partial U^B} \cdot \frac{\partial U^B}{\partial R}$ ' 0. Note that any good which yields value to person B, whether public or private, would yield existence value to person A.

Now suppose the motive behind existence value is paternalistic altruism. (The notion of paternalistic altruism has been discussed in some detail by Collard.) If person A has paternalistic altruism solely toward person B's use of R, then (16) would be rewritten simply as

$$U^A = U^A(Y_A, R) \tag{18}$$

so that $\frac{\partial U^A}{\partial R} > 0$, $\frac{\partial U^A}{\partial Y_B} = 0$.

With these definitions we now argue that the motives which give rise to existence value are important. Consider a proposed project that would tax A and B in order to pay for an increase in R from R_1 to R_2. Suppose we ask person A the following stylized contingent valuation question:

Q* How much would you be willing to pay to have R increased from R_1 to R_2?

We would expect person A's response to be positive if he is motivated by either kind of altruism. Since A is not a user of the resource, the standard procedure would be to interpret this response as his existence value from the increase in R. However, depending on A's motives, this interpretation may be misleading.

Suppose person A's existence value stems, at least in part, from individualistic altruism. Since he is not told the value of goods that must be sacrificed (other than his own contribution) for the resource enhancement, he is not given the opportunity to compute the change in well-being of person B. Hence, there is no opportunity for a negative response. Suppose Q* is rephrased as follows:

Q** How much would you be willing to pay to have a project undertaken (postive $) or stop a project from. being undertaken (negative $) that would tax person B and increase R from R_1 to R_2?

The response to Q**, even if still positive, will very likely be lower than when no opportunity cost is presented to person A. It may even vary depending on the type of goods to be sacrificed by person B if A is motivated partly by paternalistic altruism. That is, person A's response may depend on whether person B pays in higher taxes or reduced services of some other public good. Most likely, at some level of opportunity cost, person A will become willing to pay some amount to keep the resource change from occurring. Thus, if existence value bids are partially based on individualistic altruism, contingent valuation attempts to estimate existence value must give respondents information about the size and form of the costs that others must pay when a resource enhancement project is undertaken.

In addition to altruism towards other people, it is possible that other motives could underlie existence value. Randall and Stoll have used the term "Q-Altruism" to represent altruism directed toward the resource itself. This seems plausible if the resource in question is an advanced form of animal life, but less plausible if the resource is an inanimate object. Alternatively, there may exist an underlying "environmental ethic" which is totally independent of anyone's use of environmental resources. We have no basis for judging which motives are operative. Both the presence of environmental groups, and the observed positive responses to questions eliciting existence value can be explained by altruism towards others, other motives or indirect use values. In any case, it is sufficient for our purposes simply to recognize that other motivations may exist and to note that the presence of other motivations may also be relevant to the proper design and interpretation of contingent valuation experiments.

Let us take the analysis one step further. Consider a project which increases R from R_1 to R_2, and costs C, to be paid by B, the user. B's surplus from the change (S_B) is given implicitly by

$$U^B(Y_B - S_B, R_2) = U^B(Y_B, R_1) \tag{19}$$

Suppose that $C > S_B$, i.e. user benefits are less than costs. Now we ask, under the payment scheme when B pays, how much surplus does A get from the project when he is motivated by individualistic altruism? A's surplus is given implicitly by

$$U^A(Y_A - S_A, U^B(Y_B - C, R_2)) = U^A(Y_A, U^B(Y_B, R_1)) \quad (20)$$

Since $U^B(Y_B - C, R_2) < U^B(Y_B, R_1) = U^B(Y_B - S_B, R_2)$, A must be compensated for the move and hence S_A (existence value) is negative. Thus, the aggregate benefits remain less than costs after the inclusion of existence value

$$S_A + S_B < C \quad (21)$$

because $C > S_B$, $S_A < 0$. When individualistic altruism prevails, and the user pays all costs, adding in the surplus from existence value from the nonuser does not change the benefit-cost outcome.[8]

It is reasonable to ask whether a change in the distribution of costs will make benefits exceed costs. If A is altruistic towards B, won't he help share costs? We can rewrite (20), letting w be A's share of costs and (1-w) B's share:

$$U^A(Y_A - S_A - wC, U^B(Y_B - (1-w)C, R_2)) = U^A(Y_A, U_B(Y_B, R_1)). \quad (22)$$

Expression (20) has $w = 0$. Differentiating with respect to w and observing how S_A changes gives us

$$\partial S_A/\partial w = [U_1^B \cdot U_2^A/U_1^A - 1]C \quad (23)$$

where subscripts on U indicate partial derivatives with respect to arguments.

This algebraic result tells us what we should already know. A's willingness to pay for the project will increase if he gets more utility by giving B a dollar ($U_2^A U_1^B$ is the rate of A's utility change from B's income increase) than he gets from having a dollar himself (U_1^A). While such a result can not be discarded completely, it seems extreme. Thus, if the users can't pay for the project when $w = 0$, then including individualistic altruism when nonusers share the cost, will not increase the benefits.

Let us now consider the question of whether any resource, good, action, risk or regulation can provide or deprive an individual of existence value. This bears directly on the issue of motives. Krutilla observed that historical and cultural features and perhaps rare works of art can also provide service flows to those who do not use them. This same conclusion is argued by Randall and Stoll, who suggest that many different kinds of goods and services have potentially significant existence value. Nevertheless, the prevailing view is that there is something special about natural and environmental resources that makes existence value from these resources more significant than existence value from most or all other types of goods. This view has been based on the intuition that existence value is likely to be most important for assets that are unique, irreplaceable, and long lived.

Unfortunately, there is no easy answer to the question of the extent of existence value. The answer lies with the unobserved motives that give rise to existence value. For example, if the only motive underlying an individual's existence value is individualistic altruism, then all kinds of goods consumed by others would provide existence value to the individual based on the extent of use values provided by each good. Characteristics of natural assets such as uniqueness, irreplaceability and longevity may account for large existence value, but only in as much as these characteristics increase the potential for use value from natural assets. In contrast, if the source of existence value is paternalistic altruism, then existence value could be greater from natural versus man made assets, though we know of no clear reason *a priori* why it should be.

Motives other than altruism or an environmental ethic may account for existence value. For example, it could be hypothesized that existence value from resource preservation stems from an inherent desire to preserve the status quo. Even so, it is not clear that ignoring existence value encourages too much conservation. Consider a community where a major source of livelihood is timber harvesting, so that conserving the forest means a drastic change in the structure of the community. If people have existence value for the status quo in their community, then ignoring existence value might encourage too much conservation.

This section has explored the consequences of individualistic altruism. By hypothesizing individualistic altruism as a plausible motive for existence value, we have argued that existence value could accrue from any type of good. We have further argued that individualistic altruism will not change the benefit-cost outcome. As discussed above, there are other plausible motives for existence value. In cases other than individualistic altruism, adding existence value to user benefits could change the sign of a benefit-cost analysis. Thus, it is useful to ask if there is any way to discover whether individualistic altruism is important in the sense that many people are so motivated. Without more specific information, the role of existence value in benefit-cost analysis is ambiguous.

4. Some Empirical Evidence

This section presents some preliminary results of a stylized contingent valuation experiment designed to provide information about the motives behind existence value. The study population was defined as adult (age 18 or over) residents of the Washington D.C. and Baltimore Standard Metropolitan Statistical Areas. A Random Digit Dialing Telephone Survey was used to contact 1057 indivduals in the study area. Of those contracted, 741 agreed to fill out and return a brief mail questionnaire regarding water quality in the Chesapeake Bay, and of these 741, 282 actually returned the questionnaires. The 282 respondents were grouped as users or non-users. Users were defined as all respondents who thought they might use the Bay. Respondents who felt certain that they would not use the Bay for recreation at any time in the future were defined as non-users. Non-users accounted for 16.3% of the respondents.

Because only about 70% of those contacted agreed to receive the mail questionnaire, and because only 38% of those who agreed actually returned these questionnaires, these results should not be taken as representative of the population sampled. Further, we are aware that the counterfactual nature of the questions raises some doubt about the validity of the responses. But we are interested in using the contingent valuation framework for gaining insights into motives, not computing aggregate benefits and costs.

Respondents were asked to consider a series of situations concerning public beaches surrounding the Chesapeake Bay. They were asked to assume that water quality at these beaches had fallen below a level acceptable for swimming. They were told that a clean-up project could be undertaken that would clean the beaches so that a water quality level acceptable for swimming was achieved and maintained. Then respondents were asked the following question under 4 different scenarios:

Q.1 Would you prefer that the clean-up project be undertaken?

Scenario 1. No additional information.

Scenario 2. Access to the beaches by the public is permanently denied so that even if clean, the beaches will not be used.

Scenario 3. If the project is undertaken, taxes would be raised so much that nearly everyone prefers that the project is <u>not</u> undertaken. These taxes would be paid by individuals <u>other than</u> the respondent.

Scenario 4. If the project is not undertaken, funds would instead be used to improve hospital services in selected communities surrounding the Bay. The respondent would never need to visit any of the improved hospitals, and of all the people who care, half want the beaches cleaned and half want improved hospital services.

The proportion of yes responses for users and nonusers under each scenario is given in Table 1.

Table 1. Summary Results of Contingent Valuation Experiment

Scenario Number	Proportion of Yes Responses: Users[a]	Standard Error of Difference[c]	Proportion of Yes Responses: Non-users[b]	Standard Error of Difference[c]
1	.96		.83	
2	.70	.032	.69	.088
3	.71	.032	.67	.088
4	.49	.035	.37	.091

a. The number of users is 236.

b. The number of nonusers is 46.

c. This number is the standard error of the difference between the proportion in Scenario 1 and the proportion of the given Scenario.

Responses to Q.1 under Scenario 1 are used as a control to be compared with responses under Scenarios 2 through 4. As expected, most respondents preferred that the project be undertaken under Scenario 1. Non-user responses of yes indicate positive existence value. The relatively high number of non-users exhibiting positive existence value is consistent with the results of previous studies that have estimated existence value. Note, however, that Scenario 1 is purposely ambiguous about project costs. It appears that respondents, when not told of costs to themselves or others, simply assume there are none.

With access to beaches denied under Scenario 2, the number of yes responses to Q.1 predictably declined. Since the number of nonuser responses of yes declined when access was denied, it appears that existence value, to at least some individuals, is related to others' use. Thus, altruism may be one motive that underlies existence value. However, even with access denied, most respondents preferred that the project be undertaken. This may reflect the presence of indirect use value, an environmental ethic, or any number of other motivations. Finally, it is interesting to note the closeness of user and non-user group responses under Scenario 2. Since with access denied there can be no users, yes responses from the user group will also indicate positive existence value. Thus, the proportion of users and non-users exhibiting existence value was nearly identical.

Scenario 3 differs from Scenario 1 only in that respondents were told that others would need to pay taxes to have the project undertaken. The reduced number of yes responses under Scenario 3 indicate an underlying concern regarding the income or well-being of others, i.e. individualistic altruism. Hence, the conceptual results of section 3 appear to have practical significance. Unexpectedly, a greater percentage of users changed their response than did non-users when told of the taxes.

Under Scenario 4 the number of yes responses fell dramatically compared with the responses under Scenario 1. Since less than half of the non-users preferred that the clean-up project be undertaken, it appears that existence value from improved hospital services is at least as great as existence value from clean water in the Bay. Preferences for the clean-up project or improved hospital services should not be interpreted as stemming from individualistic altruism, since respondents were told that an equal number of people preferred each project. Non-user preferences for one project or the other could be based on paternalistic altruism or some other motive. This result is not inconsistent with the hypothesis that existence value is not confined to natural assets, even if the underlying motive for existence value is not individualistic altruism,

To summarize, our results do not contradict the idea that individualistic altruism is one of the motives underlying existence value and that existence value accrues from at least some man-made goods, even if individualistic altruism is ignored. Interpretation of this experiment must, however, be made with some caution given the highly hypothetical nature of the questions posed. Nevertheless, experiments such as this one may be our only means to provide information regarding the underlying motives behind existence value.

Footnotes

[1] We take the Hicksian limit price as the appropriate price to evaluate welfare changes. That is the p_i^* that sets x_i to zero is the p_i^* derived from the following expression:

$$x_i(p_1,\ldots p_i^*,\ldots,p_m,R,u) = 0$$

Using the Marshallian limit price will miss part of the welfare change. For more details, see Hanemann.

[2] In the case of certainty, option and quasi-option value will be zero.

[3] Consider the problem of valuing changes in an asset R when x_1 and x_2 are weakly complementary to R. Suppose that $\partial U(0,0,x_3,\ldots x_n,R)/\partial R = 0$, but $\partial U(x_1,x_2,x_3,\ldots,x_n,R)/\partial R > 0$ for $x_1 > 0$ or $x_2 > 0$. I.e., this is a slight generalization of weak complementarity. The value of a change in R is given by $C(p,R_1,u) - C(p,R_2,u)$. To get this from areas under the demand for market commodities, we can aggregate across x_1 and x_2 in the following way. Let p^* be $(p_1^*,p_2,\ldots p_n)$ be the current prices and the price that sets x_1 to zero, given the other prices, R and u. Let p^{**} be $(p_1^*,p_2^*,p_3,\ldots p_n)$ be the current prices and the prices that set x_1 and x_2 to zero, when p_2^* depends on p_1^*, the other p's, u, and R. Then under weak complementarity $\partial C(p^{**},R,u)/\partial R = 0$. Consider the value of a change in the price vector from p to p^{**}.

$$C(p^{**},R,u) - C(p,R,u) = \int_{p_1}^{p_1^*} C_1(p,p_2,\ldots p_n,R,u)dp + \int_{p_2}^{p_2^*} C_2(p_1^*,p,p_3,\ldots p_n,R,u)dp$$

The areas on the right hand side represent, first the area under the Hicksian demand for x_1 given current prices for $x_2,\ldots x_n$, and second the area under x_2, given $p_1^*,p_3\ldots p_n$. When R_1 changes to R_2 when compute

$UV = -[C(p,R_2,u) - C(p,R_1,u)]$ = change in area under x_1, given $p_2,...p_n$

+ change in area under x_2, given $p_1^*, p_3,...p_n$,

so that we can get the value of resource changes from commodity demand curves. There are two implications of this result. First,. to get the use value from other than <u>in</u> <u>situ</u> use, one must add values across all possible uses. Second, when adding values, each successive value must be conditional on zero levels of all previous uses.

4 Smith, Desvousges and Freeman suggest some of the difficulties in estimating offsite demand. See pages 6-7.

5 This issue is also investigated by Richard Bishop and Kevin Boyle in preliminary work.

6 These motives are labelled utility-related and commodity-related by Collard(p.7). In an apt phrase, Collard also describes paternalistic preferences as "meddlesome".

7 The principal results of this section have been shown to hold for any number of users and nonusers, see Madariaga and McConnell (1984).

8 This result may not hold in the case of N users if the nonuser is more altruistic toward one group of the users than another group, see Madariaga and McConnell p. 11.

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A TIME-SEQUENCED APPROACH
TO THE ANALYSIS OF OPTION VALUE*

by

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A Time-Sequenced Approach to the
Analysis of Option Value

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1. Introduction

Burton Weisbrod's 1964 seminal article on option value spawned a large literature which addresses the following question: will an individual who is uncertain about his or her future demand for a good be willing to pay a premium, in excess of the expected value of use, for the right to retain the option of future use? This difference between maximum sure willingness-to-pay for the option of future use (option price) and the expected value of future use (the mathematical expectation of Hicksian consumer surplus) is option value.

It generally is conceded that when preferences are uncertain, option value can be positive or negative (Smith, 1983, and Bishop, 1982, provide overviews of this literature). These results are of dubious theoretical interest, but of some practical importance.

They are of dubious theoretical interest because, given current institutions, the option ~~value~~ price is the correct ex-ante measure of welfare change under uncertainty (Anderson, 1979). If compensation for a change in regime could be exacted ex-post, after uncertainty was resolved, then the expectation of Hicksian equivalent variation would be an appropriate ex-ante measure of welfare change. Alternatively, if contingent claims markets exist, then the expected value of equivalent variation again is appropriate (Graham, 1981). However, neither contingent claims markets nor the ability to determine ex-post compensation exist. Therefore, it may be concluded that option ~~value~~ price is relevant to measuring welfare changes. under uncertainty and expected consumer surplus is irrelevant. Why then should we study option value?

The answer to this good question is that the sign and size of option value is of considerable practical importance in project analysis. Individual option prices may be assessed by contingent valuation techniques, but these analyses are quite expensive to undertake. One-way tests for project acceptance based on expected surplus would be available if the sign of option value is determinate. For, if a project passed (failed) a benefit-cost test which uses expected surplus measures and it is known that option value always is positive (negative), then the project could be accepted (rejected).

Naturally, this approach leaves a zone of indeterminancy, which may be filled only if the magnitude of option value is known. As well, if the issue is the optimal size of a project, then the magnitude of option value, and not just its sign, must be known. Of course, this is equivalent to saying that you need to know option price. This has led some investigators (Freeman, 1984, and Smith, 1984) to seek a bound for option value. Unfortunately, useful analytical results along these lines have been difficult to obtain.

Most of ths option value literature has dealt with Weisbrod's original notion of demand uncertainty. The difficulty that arises in establishing a sign for option value is the need to compare the marginal utility of income across states: with different utility functions in each state, nothing definite can be said in this regard. This realization led Bishop (1982) to consider supply-side options. That is, if demand for a resource is certain but its stability is uncertain, then the problem of state-dependent marginal utility of income is eliminated and the sign of option value can be established. Freeman (1985) has pointed out that Bishop only studied one case of supply-side uncertainty and concluded that in the other cases, option value again is indeterminate.

The assumption of the supply-side analyses that demand is certain, but supply is not, seems relevant to many current resource policy issues. As well, based on the positive analytical results obtained by Bishop (1982), more work along these lines appears warranted. In this paper, we investigate supply-side option value.

In the option value literature, analyses most often have been based on static models and have used the common postulate that individual preferences satisfy the von Neumann-Morganstern axioms and, hence, have an expected utility representation. In these analyses, little attention has been paid to underlying choices and constraints. This is natural, given the well-known foundation of expected utility analysis. However, we argue in this paper that this possibly has led to a misrepresentation of actual choice situations of interest in policy discussions.

In particular, it seems that inadequate attention has been paid to temporal aspects of the risky choices at issue, and the timing of possible resolutions of uncertainty relative to the time of when choices must be made. Consideration of temporal risk (in the sense of Dreze and Modigliani, 1972) undermines the expected utility foundation on which previous research has been based. Since most, if not all, actual choices involve temporal risk, this appears to be a serious problem.

The issue of time sequencing has been raised in the option value literature in the guise of quasi-option value (Arrow and Fisher, 1974). Here, the central issue is the timing of choices relative to the timing of resolution of uncertainty. Specifically, Arrow and Fisher and others (see Henry, 1974; Epstein, 1980; Hanneman, 1983; and Grahm-Tomasi, 1983) seek to determine if the prospect of learning reduces the benefits of implementing irreversible investments relative to the case when learning is ignored. The general result is that, even under risk neutrality, there is a benefit to maintaining flexibility (a quasi-option value of not undertaking irreversible investment-) due to expected learning possibilities. In fact, Conrad (1981) suggests that quasi-option value is equal to the expected value of information. Here, we very briefly address quasi-option value (QOV)(Smith, 1983 calls this time-sequenced option value) and its relationship to the time sequenced approach taken here.

The paper is organized as follows. In the next two sections, we remind ourselves using a certainty model of what we wish to measure in the stochastic case and how these measurements can be used to select a project. Section 2 addresses individual welfare change measures, while Section 3 provides a review of how a planner could use information on individual welfare change to choose a project. In Section 4, we very briefly discuss possible sources of uncertainty. Section 5 contains an analysis of supply-side option value in a setting where there is no temporal risk and individuals have standard von Neumann-Morganstern utility functions. We provide an alternative approach to that used by Bishop (1982) and Freeman (1985) and are able to obtain some positive results. In the sixth section, we study the problems introduced by a move to temporal risk and derive several results from this literature in terms of our model of supply-side uncertainty. The results here are quite negative: temporal risk greatly. complicates the study of option value. The next section shows in the case of uncertainty how the planner could use individual welfare change measures to select a project. This section also addresses quasi-option value. The final section provides a discussion and points out some empirical implications.

It should be stressed at the outset that this paper is exploratory in nature. It represents an attempt to draw inferences from the general economic literature on temporal risk for the modeling of option prices and option values in the analysis of projects with uncertain environmental consequences. There remains a great deal of work to be done. We seek here to illustrate the kinds of difficult questions that arise when time is composed with uncertainty in the study of welfare change and project appraisal.

2. A Certainty Model: The Individual

In this section, we set out a simple model of a project in a dynamic setting and study measures of welfare change. This will serve as a foundation for the stochastic models to be analyzed in the sequel. It also has some important implications for project analysis which carry through to the stochastic case and, therefore, to the study of dynamic option prices.

The individual has preferences over alternative sequences of goods consumed and environmental quality. Let $c_t \in E^n$ (Euclidean n-space) be a vector of consumption goods at date t. Included in c_t are labor supplies (measured as negative) as well as visits to recreation areas. Let $c = (c_1, \ldots, c_T)$ be a sequence of such consumptions; the individual's time horizon is date T. Prices of consumption goods are given by the spot price vector $p_t \in E^n$. This includes the prices of visits to recreation areas.

The level of environmental quality at various locations at date t is given by a vector $q_t \in E^m$. This vector is exogenous to the individual. However, as the individual has preferences over alternative quality vectors, these have components measured in an "individual payoff-relevant" fashion. The vector q_t will depend on the "output" of a "project" that is being anticipated. I introduce this with some generality. A project is represented by a sequence of points on the real line which may be thought of a "project size." This is a sequence $v = (v_1, \ldots v_\tau)$. Of course, the project may outlive the individual; generally $\tau \neq T$. Often, we have a project represented In the literature by

$$v_t = \begin{cases} 0 \text{ if the project is not implemented} \\ 1 \text{ if the project is implemented} \end{cases} \quad \text{all } t.$$

But this is not necessary and the more general approach allows alternative "phasings" of projects, which as we will see below, may be important under uncertainty.

The project affects payoff-relevant environmental quality variables via a biological/physical process function. Thus, a project may affect fish populations of relevance to recreationists by controlling amounts of a pollutant which is detrimental to ecosystem functioning more generally. In a dynamic model, the history of outputs of a project, as well as the history of environmental quality will affect current environmental quality. This can be captured by specifying a difference equation which governs the time path of environmental quality which does not have a Markovian structure. Let

$$\hat{v}_t = (v_1, v_2, \ldots, v_{t-1})$$

$$\hat{q}_t = (q_1, q_2, \ldots, q_{t-1}).$$

Then

$$q_{t+1} = f(\hat{v}_t, v_t, \hat{q}_t, q_t). \tag{1}$$

We now turn to individual preferences. We assume that all individuals are finite-lived. Let $z_t = (c_t, q_t)$ be a consumption goods/environmental quality bundle at date t $(z_t \in E^n \times E^m)$ and let $z = (z_1, \ldots, z_T)$. For notational convenience, we let $Z = E^{nT} \times E^{mT}$. The following axioms concerning individual behavior are posited to hold.

Axiom 1.1: Each individual's choices from Z are represented by a binary relation R on Z where R is a weak order and R is monotonic.

Axiom 1.2: Let ξ be the usual topology on Z. Then $\{z: z \in Z, z R y\} \in \xi$ and $\{z: z \in Z, y R z\} \in \xi$ for every $z, y \in Z$.

We have the well-known representation theorem.

Theorem 1.1: If individual preference orderings satisfy axioms 1.1-1.2, then there exists a real-valued utility function U(z), continuous in the usual topology on Z, such that z R y iff U(z) > U(y).

Proof: Fishburn (1970) theorems 3.1, 3.5, and Lemma 5.1.

We now turn to the individual's budget constraint. Let $\alpha \varepsilon (0,1)$ be the (constant for convenience) one-period, riskless market rate of interest at which individuals can borrow and lend. The Individual has an exogenous sequence on non-wage incomes $\{w\}_t^T$. Then the budget constraint may be written

$$B(p^T,w,\alpha) = \{C \varepsilon E^{nT} : \sum_{t=1}^{t=T} \alpha^{t-1} p_t^T \cdot c_t \leq \sum_{t=1}^{t=T} \alpha^{t-1} w_t; \ c \varepsilon C \}$$

where $p^T = (p_1, \ldots, p_T)$, $w = (\sum_t \alpha^{t-1} w_t)$ and $C \subset E^{nT}$ is the set of feasible consumptions.

It is natural to impose the following assumptions:

A1: $B(.)$ is non-empty.

A2: $w_t \leq \bar{w} \infty$ for all t.

Under assumption A2, it is clear that $B(.)$ is compact in E^{nT}.

Let

$$V(p^T,w,q^T,\alpha) \equiv \sup_c (U(z) : c \varepsilon B(p^T,w,\alpha)),$$

where $q^T = (q_1, \ldots, q_T)$.[1/] Since u is continuous and B is compact and non-empty, the supremum is attained.

In a world of certainty, we can define measures of welfare change using this intertemporal indirect utility function. Let (p^{oT},q^{oT}) be the initial situation and let $(p'^T,q'^T$ be the situation subsequent to implementation of a project. The compensating variation (cv) and equivalent variation (ev) are defined implicitly by

$$V(p^{oT}, w, q^{oT}\ \alpha) = V(p'^{T},\ w-cv,\ q'^{T},\ \alpha) \qquad (1)$$

$$V(p'^{T},\ w,\ q'^{T},\ \alpha) = V(p^{oT},\ w+ev,\ q^{oT},\ \alpha). \qquad (2)$$

An important special case of this arises when the utility function U is separable. Here, we impose more structure on preferences by means of the following axiom.

Axiom 1.3: $(z : z \in Z,\ z\ R\ y)$ and $(z : z \in Z,\ y\ R\ z)$ both are open in the usual topology on Z (continuity) and are convex.

To discuss separability and the existence of instantaneous utility functions, we reconsider the sequence z. Recall $z_t \in E^n \times E^m$; we then constructed z by considering the T-fold Cartesian product of E^{n+m} with itself and considered z to be an element of this space. Now, we consider preferences on each z_t individually. Thus, we let $Z = \Pi_{t=1} Z_t$, where (Z_t, ξ_t) is a topological space for each t. Let $\xi = \Pi_t \xi_t$ be the product topology for Z. It is well known that if each (Z_t, ξ_t) is a connected and separable space, then (Z, ξ) is connected and separable in the product topology. Therefore, it makes sense to discuss properties of the instantaneous utility functions which are similar to those of the overall utility function discussed above.

Let $z_{-t} = (z_1, \ldots, z_{t-1}, z_{t+1}, \ldots, z_T)$ be the consumption/quality bundle at all dates other than date t. For fixed $z_{-t} = z^o_{-t}$, the preference ordering R induces a preference ordering on Z_t given by $x_t\ R_{x_{-t}}\ x'_t$ if and only if $(x_{-t}, x_t)\ R\ (x_{-t}, x')$ for any x_t, x'_t in Z_t. We have the following statement of a separability axiom.

Axiom 1.4: For each $t \in (1, \ldots, T)$ $x_t \; R_{x_{-t}} \; x'_t$

implies $x_t \; R_{x_{-t}} \; x'_t$ for all $x_{-t} \in \prod_{i \neq t} Z_i$.

The following theorem provides a utility function representation for separable preferences.

Theorem 1.2: The preference ordering posited in Axioms 1.1 to 1.4 may be represented by a continuous, quasi-concave function $U: \prod_t Z_t \to E$ which may be written

$$U(z) = \hat{U}(u_1(z_1), \ldots, u_T(z_T))$$

where $u_t : Z_t \to E$ and $\hat{U} : E^T \to E$, and $\hat{U}$ as well as each u_t is increasing, continuous (in the product topology and usual topologies respectively) and quasi-concave.

Proof: The existence of a continuous utility function taking the separable form is proved by Katzner (1970). That the component functions $\hat{U}$ and u_t are quasi-concave if U is (which follows from axiom 1.3), is shown by Blackorby, et al., (1978), Theorem 4.1.

Let w_t be income allocated to consumption at date t, and let $B_t(p_t,w_t) = (c_t : p_t \cdot c_t \leq w_t, \; c_t \in C)$. Define $V_t(p_t,w_t,q_t) = \max_{c_t} (U(c_t) : c_t \in B_t(\cdot))$.

Then

$$V(p_t,w,q,\alpha) = \max_{\{w_t\}} \{\hat{U}(\{V(p_t,w_t,q_t)\}_{t=1}^{t=T}): \sum_{t=1}^{t=T} \alpha^{t-1} w_t \leq w\}.$$

The instantaneous indirect utility functions can be used to define instantaneouc measures of welfare change, i.e.,

$$V_t(p_t^o, w_t^o, q_t^o) = V_t(p_t', w_t' - cv_t, q_t')$$
$$V_t(p_t', w_t', q_t') = V_t(p_t^o, w_t^o + ev_t,\ q_t^o), \text{ for } t \in [0,T].$$

Here, when the project is implemented, the consumer may respond by reallocating income through time as well. This point is crucial, for it creates the following inequality:

$$V(p'^T,\ w'^T - cv,\ q') = \hat{U}(\{V_t(p_t',\ w_t - cv_t,\ q_t')\}_{t=0}^{t=T}) \leq$$
$$V(p'^T, \sum_{t=1}^{t=T} \alpha^{t-1}(w_t - cv_t), q'^T) = V(p'^T, w - \sum_{t=1}^{t=T} \alpha^{t-1} cv_t, q'^T).$$

This implies, since V is increasing in its second arguement, that

$$cv \geq \sum_t \alpha^{t-1}\ cv_t.$$

Thus, if the present value of consumer surplus is non-negative, so is the present value welfare change measure cv.

Similarly,

$$\sum_t \alpha^{t-1}\ ev_t \geq ev,$$

whence if the present value of equivalent variations is negative, so is the true welfare charge measure. These give two one-way tests, but leaves a zone of indeterminancy. Moreover, we have the following theorem.

Theorem 1.3: There is no U with U, $\hat{U}$ and $\{u_t\}$ continuous, increasing, and quasi-concave, such that the present value of instantaneous cv_t or ev_t is an exact index of welfare change for all projects.

Proof: Blackorby, Donaldson and Moloney (1984).

Before turning to an assessment of how the equivalent variation measure of welfare change for individuals can be used in making choices among projects by a social planner, we introduce the intertemporal expenditure function and discuss briefly the money metric measure of welfare change.

Dual to the lifetime indirect utility function introduced above is the lifetime expenditure function defined by

$$V(p^T, w, q^T, \alpha) = V^o \Leftrightarrow E(p^T, q^T, \alpha, V^o) = w.$$

The money metric (see McKenzie and Pearce, 1982) is defined by

$$Y(v) \equiv E(p^T(0), q^T(0), \alpha, V(p^T(v), w, q^T(v), \alpha))$$

where $p^T(0)$ and $q^T(0)$ are prices and environmental quality in the absence of the anticipated project. The definition of the expenditure function shows that

$$ev(v) = Y(v) - w. \tag{2}$$

The money metric gives minimum the cost of achieving the level of the utility with the project, when the project has not been implemented. Since Y is a monotonic increasing function of an indirect utility function, it is itself an indirect utility function. Importantly, both the ev and the money metric are invariant to increasing monotonic transformations of the underlying ordinal utility function.

The money metric and equivalent variations possess an important property that the compensating variation does not have. The cv is not an exact measure of welfare change in that it may not correctly rank several projects relative to a base project, although it will correctly make pairwise comparisons (Hause, 1975; Chipman and Moore, 1980). Thus, we restrict our attention in what follows to the ev and Y measures of welfare change.

To sum up the results of this section, the equivalent variation and money metric are useful measures of individual welfare change due to the implementation of a project. In a dynamic setting, these should be defined relative to the lifetime indirect utility or expenditure functions. This would seem to underscore the usefulness of survey techniques in eliciting willingness-to-pay since lifetime compensation measures (or their annualized equivalent) can be directly assessed. However, the lifetime approach does create a few difficulties for the definition of an appropriate criterion for selection of a project by the planning authority. We address this issue, at least partially, in the next section.

3. Project Selection under Uncertainty

The difficulties of moving from individual to social valuations of projects are of two kinds. The first is the much discussed possibility of providing an axiomatic foundation for a social preference ordering or welfare function which is based on individual orderings. We do not address this issue here, and merely assert the existence of a preference ordering for the planning authority which has certain properties. The second difficulty derives from our focus on lifetime indirect utility functions in Section II. In particular, if it is asserted that the planner has preferences over indirect utilities, and we do not assume that each "generation" consists of a single individual (see, e.g., Ferejohn and Page, 1978), then some work is required to establish a benefit-cost foundation for social choices.

The individual theory above used the sequences p^T and q^T, which are sequences with terminal date corresponding to the individual's planning horizon. These are subsequences of $p_{\bar{\tau}} = (p_1,\ldots,p_{\bar{\tau}})$ and $q_{\bar{\tau}} = (q_1,\ldots,q_{\bar{\tau}})$, where $\bar{\tau}$ is the horizon relevant to the planning authority. These price and environmental quality sequences depend on the project that is implemented. The environmental quality sequence depends on the project as represented by equation (1). In the sequel we write $q_{\bar{\tau}}(v)$ to denote this dependence. Being purposely vague, we write $p_{\bar{\tau}}(v)$ as well. We assume that both of these functions are unique without specifying conditions under which this will be true. Note that for t $\varepsilon(\tau, \bar{\tau})$

$$q_{\tau+s+1} = f((\hat{v}_\tau, 0^s), 0, \hat{q}_{t+s}, q_{t+s}),$$

where 0^s is the zero vector in E^s. Similarly, we let $p_t = p_t(0)$ for $t \;\varepsilon\; (\tau, \bar{\tau})$.

The set of possible projects is given by $\Delta \subset E^{\tau}$, $\Delta = \{v \in E^{\tau} : v$ is feasible$\}$. We say that an individual cares about a project if his/her. lifetime indirect utility varies with changes in v. Formally, we say that Agent i cares about the project set Δ if $V(p^T(v), w, q^T(v), \alpha) \neq V(p^T(v'), w, q^T(v'), \alpha)$ when $v \neq v'$ for some v, v', $\varepsilon\ \Delta$.

There are several ways in which an individual might not care about a projfct. If the individual is not alive, then (presumably) $V^i(\cdot) = 0$ for all $v \in \Delta$. As well, some prices might not depend on the project and an individual might not consume any of the goods (including recreation) with project-sensitive prices. If V^i is independent of changes in environmental quality when consumption of recreation is zero and the individual does not care about price changes for goods (s)he does not consume, then (s)he will not care about the project. This is the case of "weak complimentarity" discussed in the valuation literature (Bradford and Hildebrandt, 1977).

Let $M^i = \{t : i$ cares about Δ at $t\}$, and let $t(i) = \inf \{t : t \in M^i\}$. To avoid mathematical complexities which are not of concern in this paper, we impose

A3.1: The number of agents at each date t is finite.

A3.2: $\bar{\tau} < \infty$.

A3.3: $t(i) \leq \bar{\tau} - T^i$ for all i.

Let ${}^tI = \{i : t(i) = t\}$. We denote the power of ${}^tI$ by I^t. Individual i's planning horizon is given by T^i; purely to ease notational burden, we assume that $T^i = T$ for all i.

The vector of lifetime indirect utilities is a vector in E^I, where $I = \prod_t^{\bar{\tau}} I^t$. By A3.1 and A3.2, this is a finite-dimensional space. The planning authority is presumed to have preferences on E^I as given in the following axioms.

Axiom 3.1: The planner's preferences are represented by a binary relation $P \subset E^I \times E^I$ where P is a weak order, which is monotonic and continuous in the usual topology.

Under axiom 3.1, we can represent P by a real valued social welfare function.

Theorem 3.1: If the planner's preferences satisfy axiom 3.1, then there exists $W : E^I \rightarrow E$, with W continuous and such that $W(V^1,\ldots,V^I) > W(\overline{V}^1,\ldots\overline{V}^I)$ if and only if $(V^1,\ldots, V^I)\, P(\overline{V}^1,\ldots, \overline{V}^I)$.

Proof: Fishburn (1970).

Theorem 3.1 establishes a social welfare function defined on sequences of lifetime indirect utility profiles. However, a problem arises in this approach. The arguments of W are individual utilities, which can be subjected to an arbitrary monotonic transformation with affecting underlying behavior. Undertaking such a transformation may drastically change the social rankings involved. Clearly, this is an undesirable characteristic for a social welfare function to have. Rather than dealing carefully with specification of W, it is more convenient to measure the arguments of W such that they are invariant to such monotonic transformations. The money metric described in the previous section is an obvious candidate.

Furthermore, we are interested in deriving social rankings of alternative projects induced from this ranking of utilities. That is, we seek a ranking p* defined by v P* v' if and only if g(v)P g(v'), where $g: \Delta \rightarrow E^I$ given individual lifetime utility vectors as a function of projects. An important special case for which this is straightforward and which will be useful when uncertainty is introduced is where the social welfare function is linear. Thus, we impose

A3.4: $W(V^1,\ldots, V^I) = \sum_{i=1}^{i=I} b_i V^i.$

The implementation of a project entails a cost and, therefore, the central planner must devise some method of financing the effort. We assume that lump-sum financing is possible. Let the spot expenditures required to implement a project v be given by

$$k(v) = (k_1(v), \ldots, k_\tau(v)).$$

The planner has several options for financing project v. A financing scheme is a vector of payments $s(v) = (s^1(v), \ldots, s^I(v))$ which specifies $s^i(v)$, the payment by agent i to finance project v. The set of feasible financing schemes is given by

$$S(v) = \{s(v) : \sum_{t=1}^{t=\bar{\tau}} \alpha^{t-1} \sum_{i=1}^{i=I^t} s^i(v) \geq \sum_{t=1}^{t=\tau} \alpha^{t-1} k_t(v)\}$$

The central authority will choose a feasible project/financing scheme pair so as to maximize social welfare. That is, it will solve

$$\max_{v\epsilon\Delta} \sum i \; b_i \; Y^{*i} (v),$$

where

$$Y^{*i}(v) = Y^i(v,s^{*}i(v)) = E^i(p^T(0),q^T(0),w^i,\alpha, V^i(p^T(v),w^i-s^{*i}(v),q^T(v), \alpha))$$

for

$$s^*(v) \; \epsilon \operatorname*{argmax}_{s(v)\epsilon S(v)} \sum_i b_i Y^i(v,s^i(v)).$$

It is interesting to point out that the following theorem governs a relationship between choices of v and choices of lifetime indirect utility vectors.

Theorem 3.2: v P* v' if and only if

$$\sum_i b_i \; [ev^i(v) - ev^i(v')] > 0.$$

Proof: By theorem 3.1, $\vec{V}\ P\ \vec{V}'$ iff $W(\vec{V})>W(\vec{V}')$, where $\vec{V}=(V^1, \ldots, V^I)$. whence by A3.4, $\vec{V}\ P\ \vec{V}'$ iff

$$\sum_i b_i\,[V^i(v) - V^i(0) - (V^i(v') - V^i(0))] > 0.$$

Since Y^i is a utility indicator and $Y^i(0) = w^i$,

$\vec{V}\ P\ \vec{V}'$ iff $\sum_i b^i[Y^i(v) - w^i - (Y^i(v') - w^i)] > 0,$

By definition of P* and by (2), the result follows.

The magnitude of $ev^i(v)$ will depend on the financing scheme used. It is not possible to separate these decisions. McKenzie (1983, chapter 8) shows how the ordinal properties of W can be used to determine losses due to use of non-optimal financing schemes.

In this section, we have shown how to elicitation of equivalent variations for lifetime utility can be used to make social choices among prjects. In particular, for a planner with "welfare weights" given by a linear social welfare function, a project will be selected based on the maximization of the weighted sum of the equivalent variations for that project, given the use of an optimal financing scheme.

4. Uncertainty

We now turn to possibilities for generalizing the framework developed in the previous section to the case of uncertainty. As discussed in the introduction, it is critical that when uncertainty is addressed, that it is clear what it is that uncertainty surrounds, who faces the uncertainty, and what that agent can do about it. In this section we investigate individual uncertainty. In the next section we will discuss uncertainty on the part of the planner.

There are several ways that uncertainty can enter the model developed in Section II of the paper. We identify here several that seem relevant in the option value literature:

(i) Ecological uncertainty. Given a $\nu \in \Delta$ it is not known what level of environmental quality will obtain. This may be represented by making (1) a random function. There are two ways to capture this, each representing a different source of uncertainty.

First, we could think of the function f itself as being unknown. That is, we may not know how ecosystem function maps projects into environmental quality. Second, even if the true f is known, the sequence of quality outcomes might be stochastic. In fact, both of these are operating to make uncertainty relevant. If the former operated without the latter, a simple experiment at date zero would resolve all of this type of uncertainty. If the latter operated without the former, then learning about ecosystem function would not be possible unless it is interpreted as trying to discover the probability law driving the stochastic process; clearly biological investigation seeks more than this.

(ii) Economic uncertainty. It seems plausible to assume that future prices and incomes are risky.

(iii) Preference uncertainty. The majority of the literature. on option value has investigated the implications of state-dependent preferences (demand uncertainty) where individual preference orderings are uncertain.

(iv) Political/Regulatory uncertainty. The project itself may be risky. The project may entail some enforcement which may be applied at various levels in the future or may no yield compliance.

(v) Social uncertainty. When confronted with a project which can be implemented at alternative levels and where aggregate willingness to contribute to funding the project is involved, individuals may hold uncertainty about the contributions of other agents. This often is discussed in terms of strategic bias in contingent valuation assessments of willingness-to-pay where the presumption is free-riding behavior, but this is a special case of more general problems of social interdependence in provision of public goods.

(vi) Planning uncertainty. Even if agents know their own preferences, the planning authority may not know them. Thus, the planning authority may have uncertainty about preferences even if individuals do not.

The theoretical option value literature has focused on uncertainty of types (i), (ii), and (iii) above, though one analysis of time-sequenced option value has examined uncertainty of type (iv) (Graham-Tomasi, 1983). The ecological uncertainty has taken a particular form in the literature on supply-side option value (Bishop, Freeman, 1985), in which quality either is good enough to allow a particular recreational activity or quality deteriorates to the point where the activity no longer is available. Thus, just two states are possible. It is common in this literature to see this uncertainty represented as price uncertainty, with the entry fee for activity at the rate equal to some finite price of the activity is available and an infinite price if it is not. We present a generalization of this approach below. Usually, though not always (Hartman and Plummer, Freeman, 1984) it is assumed that prices of other goods and income are non-stochastic.

5. Individual Uncertainty with an Expected Utility Representation

The majority of analyses of option value employ a static model and use an expected utility representation of individual preferences. In this section we take a similar approach to modelling preferences and investigate extensions of the material developed above to the case here. We focus on ecological uncertainty; that is, we focus on supply-side uncertainty. Given a project, there is a probability structure on environmental quality induced by the probability structure on ecosystem functioning. To gain an expected utility representation, we restrict ourselves to analysis of a static problem. In section VII we consider a two-period problem.

Let $(\Omega, \mathcal{F}, \mu^{\omega})$ be a probability space, We turn the function f defined in (1) into a random function representing the two sources of ecological uncertainty in the following fashion. Let

$$\Phi = \{f\colon E^m \times E \times \Omega \to E^m\colon f \text{ is Borel measurable relative to } \mathcal{F} \text{ for all fixed } (g,\nu) \in E^m \times E \text{ and } \mu^{\omega} - \text{integrable}\}.$$

We assume

$$\text{A5.1:}\quad f \in (f^1, \ldots, f^F) \quad f^i \in \Phi \text{ for all } i, \text{ with } \pi^i = \text{Prob}\,[f = f^i].$$

Then, the induced probability measure on environmental quality, conditional on the project V and initial (non-random) enviornmental qualtiy q_o is

$$\mu^{\nu}(Q_1) = \sum_i \mu\{\omega \in \Omega\colon\ f^i(q_o, \nu, \omega) \in Q_1\}\, \pi^i$$

for $Q_1 \in \mathcal{B}(E^m)$, the Borel set of E^m.

In this section we suppose that the individual has preferences on the space of probability measures on (Q_1) which satisfy the non-Newmann and Morganstern axioms. Formally, let L be the space of lotteries on environmental qualtiy, i.e.,

$$L = \{\mu^{\nu}(Q_1): \ \nu \in \Delta\}.$$

A::iom 5.1: The individual's choices from L are representable by a binary relation R which satisfies

(i) is a weak order

(ii) $(\mu^1 \, R \, \mu^2) \Rightarrow \alpha\mu^1 + (1-\alpha)\mu^3 \, R \, \alpha\mu^2 + (1-\alpha)\mu^3$ for $\mu^1, \mu^2, \mu^3 \in L$ and $\alpha \in (0,1)$

(iii) $(\mu^1 \, R \, \mu^2)$ and $(\mu^2 \, R \, \mu^3) \Rightarrow \alpha\mu^1 + (1-\alpha)\mu^3 \, R \, \mu^2$ and $\mu^2 \, R \, \beta\mu^1 + (1-\beta)\mu^3$ for some $\alpha, \beta \in (0,1)$ and $\mu^1, \mu^2, \mu^3 \in L$.

Then we can show

Theorem 5.1: For all μ^{ν}, $\nu \in \Delta$, let the sets $\{\mu \, R \, \mu^o\}$ and $\{\mu \in L: \ \mu^o \, R \, \mu\}$ be open in the weak topology and let the preference represented by μ of the previous section be strictly conve::. Then there e::ists a continuous function V: $E^{3n + 2m+1} \times (0,1) \rightarrow E$ such that

$$\mu \, R \, \mu^o \Leftrightarrow \int_{\Omega} V(\cdot) d\mu > \int_{\Omega} V(\cdot) d\mu^o,$$

where

$$V(p_0, p_1, \alpha \, w, c_0, q_0, q_1) = \sup_{C_1 \in B(p_0, p_1, w, c_0)}$$

$$U(c_0, q_0, c_1, q_1, \text{ for } B(\cdot) = \{c_1: \ \alpha P_1 C_1 \leq w_1 + \alpha \, w_2\}.$$

Moreover, this supremum is attained, and

$$C_1^* \in \arg\max_{C_1 \in B(\cdot)} U(\cdot) \text{ is continuous.}$$

Proof: The existence of the function V follows from Axiom 5.1 and Fishburn (1970), Theorem 8.4. Continuity of V follows from openness of the upper and lower contour sets (Varian, 1978). That the supremum is attained derives from the Weierstrauss Theorem, the continuity of u and the compactness of $B(\cdot)$. Upper semi-continuity of c_1^* follows from the ma::imum principle of Berge (1963); but c_1^* is unique due to the strict convexity of the upper contour sets of μ, and therefore c_1^* is continuous.

We now are in a position to define welfare measures for changes in the measure μ^{ν} due to choices of $\nu \in \Delta$. Let μ^o be the measure induced by project $0 \in \Delta$. Similary, let $F^o(q_1)$ and $F^{\nu}(q_1)$ be the probability distribution functions for μ^o and μ^ν. There is a one-to-one correspondence between μ and F (Ash, 1970). We define the compensating option price (COP) and equivalent price (EOP) implicitly by

$$\int_\Omega V(p, q, \alpha, w - COP(\nu))d\mu^\nu = \int_\Omega V(p, q, \alpha, w)d\mu^o.$$

$$\int_\Omega V(p, q, \alpha, w)d\mu^\nu = \int_\Omega V(p, q, \alpha, w + EOP(\nu))d\mu.$$

These, of course, are natural analogs of the cv and ev measures of welfare change defined in Section II. In most of the option value literature, the COP measure is called the option price (e.g. Smith, 1983; Freeman, 1985). As discussed in the introduction, considerable attention has focused in this literature on the relationship between COP and the e::pected value of consumer surplus. The motivation for this concern is two-fold. First, in the absence of contingent claims markets, or the ability to e::tract e::-post compensation from agents, it is though that COP is the proper measure of e::-ante WTP for the pro= ject. Second, since consumer surplus measures are used to determine project choice (as in Section III of this paper), investigators are interested in whether use of consumer surplus over or under estimates true e::-ante WTP.

One difficulty with this discussion is that the COP measure only is an appropriate inde:: of welfare when binary choices among projects are being made. This is for the same reason that the cv measure is inappropriate. Formally, we have the following theorem.

Theorem 5.2: The $COP(\nu)$ measure is not a valid measure of welfare change.

Proof: Define certainty equivalent environmental quality levels $CEQ(p, w, \alpha, c_o, \mu)$ by

$$\int V(p, w, \alpha, c_o)d\mu = V(p, w, \alpha, c_o, CEQ(\cdot)).$$

Then by definition,

$$V(p, w - COP(\nu), \alpha, c_o, CEQ(p, w, \alpha, c_o, \mu^\nu)) =$$
$$V(p, w, \alpha, C_o, CEQ(p, w, \alpha, C_o, \mu^o)).$$

But, by arguments in Chipman and Moore (1980), **COP(ν)** only is a valid index for binary choices. If there is more than one $\nu \in \Delta$ other than $\nu = 0$, COP may not rank these correctly.

Thus, we suggest that attention be focused on the equivalent option price, since, by a similar argument, EOP is a valid measure of welfare change. In their analyses of option value, Schmalensee (1972) and Bishop (1982) uses the EOP. Of course, whether EOP or COP is used will not matter if there are only two possible projects.

As discussed above, much of the option value literature is concerned with the relationship between an ex-ante measure such as COP or EOP and the expected value of ex-post measures. Freeman (1985) has pointed out that the supply-side of many of these analyses is a special case of the more general case of a change in distribution that he (and we) consider. In particular, these analyses presume that only type (iii) uncertainty, demand uncertainty exists, substitute two degenerate measures μ^o and μ^ν on the supply side, and let m = 1.

Briefly, the formulation is as follows. Let V be the individual's indirect utility function, a Borel measurable function of $\omega \in \Omega$, and let μ^D be a probability measure on the **σ-algebra** on Ω. On the supply side, assume that μ^ν and μ^o both are degenerate, assigning probability one to outcomes q^ν and q^o respectively. Then, in state β, the equivalent variation $ev(\beta)$ is

$$V^\beta(p, q^\nu, \alpha, w) = V^\beta(p, q^o, \alpha, w + ev(\beta)),$$

and the expected equivalent variation is

$$\int ev(p)dF^D(\beta).$$

We have the following much-discussed result.

Theorem 5.3: With μ^o and μ^ν degenerate and μ^D non-degenerate, EOP can be greater or less than expected equivalent variation.

Proof: The proof follows that of Bishop (1982), where our definition of ev is substituted for his.

Note that in the formulation in Bishop and elsewhere (e.g. Andersen, 1981) it is assumed that under $0 \in \Delta$, $q_1^o < q_{1min}$, where q_{min} is the minimum quality such that the site is not available. This is formalized as $q_1^o \Rightarrow c_{1j} = 0$ where c_{1j} is visits to the site and is accomplished by a pricing function $p(\nu)$ with $p_{1j}(0) = \infty$; $p_{1j}(\nu) = p_{1j} < \infty$. This formulation is not strictly necessary.

The literature which addresses ecological uncertainty in the absence of preference uncertainty is somewhat confusing regarding definitions of equivalent and compensating option price. In the definitions above, equivalent option price (EOP) uses the situation without the project as a base adn asks how much money must be given to the individual to forego the benefits induced by the project. The compensating option price (COP) uses the situation with the project as a base and asks how much can be taken away from the individual to return him or her to the pre-project level of utility.

In the analyses by Bishop (1982) and Freeman (1985) of ecological uncertainty, only two situations are compared; thus, the difficulty of ranking projects by the COP measure may not arise. However, it is important to note that the proof of Theorem 5.2 used a certainty equivalent approach. When one defines a welfare change measure for each state, then which measure is appropriate may depend on whether the before-project or after-project probability is degenerate.

Both Bishop and Freeman study a model with only two possible outcomes, one of which corresponds to a level of quality such that use of the site is zero. They then define the ex-post compensation measure in the state in which the resource is available by income change that equates indirect utility with and without the resource. This is the natural approach. Here, we consider a model with many possible states. Thus, our ex-post measure for each state is defined relative to with and without project realizations of quality. That is, if

$q^\circ \in Q^\circ$ is the realization without the project and $q^\nu \in Q^\nu$ is the realization with project $\nu \in \Delta$, then $ev(q^o, q^\nu)$ and $cv(q^\nu, q^\circ)$ are defined implicitly by

$$V(w - ev(q^o,q^\nu), q^o) = V(w, q^\nu)$$
$$V(w,q^o) = V(w - ev(q^\nu, q^o), q^\nu)$$

In the most general situation in which there is risk about environmental quality both with and without the project. Then expected values of ex-post welfare measures are given by

$$\int_{Q^o} \int_{Q^\nu} ev(q^o,q^\nu)dF^\nu(q^\nu)dF^o(q^o) = \int_{Q^\nu} \int_{Q^o} cv(q^\nu,q^o)dF^o(q^o)dF^\nu(q^\nu)$$

Having chosen a base outcome given by the first argument of the ev(.,.) and cv(.,.) function (e.g., ev (q°, q^ν) gives the ev of a move from outcome q° without the project to outcome q^ν with the project), both of these will correctly compute the welfare change in each state. That is, conditional on outcome q°, the L.H.S. measure will assign the same welfare measure to two indifferent with-project outcomes q^ν. The same is true for the R.H.S. where the conditioning base event is the with-project event q^ν.

Returning to the analyses of Bishop (1982) and Freeman (1985), we consider two special cases. In the first, the situation without the project is risky, while the project provides a desirable sure outcome, and in the second, environmental quality without the project is given by a sure undesirable outcome, while the project provides a risky quality. These correspond to Case B and Case C in Freeman (1985), respectively; he notes that Bishop studies Case B.

Consider first Case B. Here, since the situation with the project is fixed, it makes some sense to use the cv measure in each state. Then, a fixed base is used for comparison to each of the risky outcomes without the project. Then, it is easy to show that the COP is greater than the expected value of the ex-post cv measures, at least for a finite number of states.

Theorem 5.4: (Bishop, 1982) Let $F^{\circ}(q)$ be non-degenerate with probability mass $\Pi^{o} = (\Pi^{o}, \ldots, \Pi^{o})$ and let $F^{\nu}(q)$ be degenerate, with Prob $[q = \overset{V}{q^{\nu}}] = 1$. Then, if $V(\cdot)$ is strictly concave and increasing in income, the COP is greater than the expectation of cv.

Proof: The cv measure in state i is defined implicitly by

$$V(w - cv^{i}, q^{n}) = V(w, q^{i}).$$

Compensating option value is defined by

$$\sum_{i} \Pi_{i}^{o} V(w, q^{i}) = V(w - COP, q^{\nu}).$$

By concavity of V(w,q) in w,

$$V(w - Cv^{i}, q^{\nu}) < V(w - COP, q^{\nu}) + (COP - cv^{i}) V_{w}(w - COP, q^{\nu}).$$

Since the LHS is equal to $V(w, q^{i})$ by definition, multiplication by Π^{i} gives

$$\Pi_{i}^{o} V(w, q^{i}) < \Pi_{i}^{o} V(w - COP, q^{\nu}) + \Pi_{i}^{o} (COP - cv^{i}) V_{w}(w - COP, q^{\nu}).$$

Summing over i yields

$$\sum_{i} \Pi_{i}^{o} V(w, q^{i}) < V(w - COP, q^{\nu}) + V_{w}(w - COP, q^{\nu}) [COP - \sum_{i}^{o} \Pi_{i} cv^{i}].$$

By the definition of COP, we get

$$0 < V_{w}(w - COP, q^{\nu}) [COP - \sum_{i} \Pi_{i}^{o} cv^{i}];$$

which provides the result.

Actually, with many possible states, our use of the cv as the ex-post compensation measure and COP as the option price, and our definition of cv in each state allows a simpler proof than that used by Bishop in the two-state world.

Ne::t, we consider Case C. Freeman (1985) uses a cv measure and proves that the sign of option value (the difference between COP and the expectation of ev) is ambiguous. We present a similar result, and also show that with an equivalent optionprice approach and use of ev in each state, the sign of option value can be determined.

Theorem 5.5: Let F(q) be non-degenerate with probability mass $\Pi^{\nu} = (\Pi_1^{\nu}, \ldots, \Pi_n^{\nu})$, and let $F^{\circ}(q)$ be degenerate with Prop $[q=q^{\circ}] = 1$. Then, with V increasing and strictly concave in income, the relationship between COP and expected cv is not determinate. A sufficient condition for COP - E(ev) to be positive is that the marginal utility income is the same for each state.

Proof: The cv in each state is defined by

$$V(w-cv^i, q^i) = V(w,q)$$

and COP is defined by

$$\sum_i \Pi_i V(w-COP,q^i) = V(w,q^{\circ}).$$

By strict concavity of V in w,

$$V(w-cv^i,q^i) < V(w-COP,q^i) + [COP-cv^i]V_w (w-COP,1^i).$$

$$\Longleftrightarrow V(w,q^{\circ}) < V(w-COP,q^i) + [COP-cv^i]V_w (w-COP,q^i)$$

$$\Longleftrightarrow \Pi_i^{\nu} V(w,q^{\circ}) < \Pi_i^{\nu} V(w-COP,q^i)+\Pi_i^{\nu}[COP-cv^i]V_{w(w-COP,q^i)}.$$

This holds for each i, whence by definition of COP,

$$0 < \sum_i \Pi_i^{\nu}[COP-cv^i]V_w (w-COP, q^i).$$

The difficulty in establishing a sign for option value is presented by the marginal utility of income. If this Is the same at (w-COP) for each q^i, then this term can be factored out to yield

$$0 < COP - \sum_i \Pi_i^{\nu} cv^i.$$

The value of an equivalent option price approach is that the marginal utility of income term appears only with a fixed state. Thus, option value is positive.

Theorem 5.6: Assume the conditions of Theorem 5.5. Then EOP is greater than E(ev).

Proof: The proof is exactly the same as for the proof of Theorem 5.4 using EOP and ev^i defined by

$$V(w-ev^i,q^o) = V(w, q_i^{\nu})$$

$$\sum_i V(w,q_i^{\nu}) = V(w-EOP,q^{\circ}).$$

The discussion of the relationship between the ex-ante measures of COP and EOP and the expected value of ex-post measure cv and ev is due to a desire to determine if use of cv and ev in project evaluation systematically over or under estimates true ex-ante WTP. We offer two observations on this. First and most obviously, knowing that expected ev underestimates EOP is not particularly useful if you don't know by how much. Thus, Smith (1984) tries to find a bound for the size of the discrepancy. Unfortunately, Smith's approach requires a fairly strong restriction on preferences and only works for two possible states. Second, most analyses of projects do not use the expected ev or cv measure. Rather, they ignore uncertainty altogether and presume that the expected outcome is the true outcome. Thus, they calculate the Hicksian welfare measure at the expected value. Formally, let

$$ev(\overline{q}^{\nu}) = ev(\int q dF^{\nu}(g))$$

$$ev(\overline{q}^{o}) = ev(\int q dF^{o}(q)).$$

If $ev(\overline{q}^{\nu}) > ev(\overline{q}^{o})$, then the project is said to make the individual better off and the analysis proceeds as in Section III. It may be possible to derive an approximation to EOP based on readily observable variables and the deterministic ev using expected values. The author will present such an approximation in a future paper. The approach seems quite promising.

6. Individual Uncertainty: Generalized Expected Utility

The model of the previous section, which predominates the option value literature, is static. We captured the static nature of this in terms of our model by assuming that C_0 is fixed and concentrating on the relationship between C_1 and q_1. As well, we assumed that C_1 could be chosen after observing q_1. When this assumption is dropped and the model becomes dynamic, there are two difficulties that arise.

First, atemporal von Neumann-Morganstem (vN-M) utility theory applied in a dynamic setting requires that preferences on income (or here, environmental quality) be defined solely on income vectors. In the language of dynamic programming, a plan for choosing actions given states induces a probability distribution on the vector of payoffs. As optimal plan (if one exists) is one that maximizes the expectation of vN-M utility function on such vectors. As pointed out by Kreps and Porteus (1978), this rules out the possibility that an individual may prefer earlier to later resolution of uncertainty. They illustrate this by the following example. Suppose the payoff vector is (5,10) with probability 1/2 and (5,0) with probability 1/2. Then under the vN-M axioms, since 5 is the first-period payoff for sure, the individual should be indifferent between a flip of a fair coin at t = 0 and a flip of the coin at t = 1 to determine which vector obtains. In fact, individuals may prefer earlier resolution of uncertainty.

Kreps and Porteus (1978, 1979) derived a generalization of atemporal vN-M theory, which they called temporal von Neumann-Morganstern utility theory. In their theory, uncertainty is dated by the time of its resolution. These entities are called temporal lotteries. They present axioms for preferences defined as these temporal lotteries which allow a temporal vN-M representation. Below, we will apply their framework to our problem concerning environmental quality.

The second problem that arises concerns induced preferences when a choice must be made before uncertainty resolves. Even if all uncertainty resolves at a single date and the underlying preferences on consumption have an expected utility representation, induced preferences will, in general, not satisfy the independence axiom and will be "non-linear in the probabilities." This has been observed by Markowitz (1959), Mossin (1969), Spence and Zeckhauser (1972), and Dreze and Modigliani (1972). Kreps and Porteus (1979) derive necessary and sufficient conditions for induced preferences in the temporal case to take the temporal vN-M form. These are quite strong. Machina (1982, 1984) has proposed an approximation approach called generalized expected utility theory, which copes with this difficulty without sacrificing the basic foundation of expected utility theory.

In this section, we develop these results in terms of our model of ecological uncertainty.

Uncertainty is represented in same way as in the previous section. We assume that the space of possible realizations of the "experiment" giving rise to environmental uncertainty is compact. Let D_t be the space of Borel probability measures on Q_t. We then have the following result:

Lemma 6.1: D_t is a compact metric space.

Proof: By assumption, f is continuous function onto Q_t for fixed q_{t-1}. By Theorem 3.5 in Kolmogorov and Fomin (1970), Q_t is compact: $Q_t \in E^m$ so it is a metric space. The result follows from Parthasarathy (1967), Theorem 6.4.

We endow D_t with the weak topology. If g(q) is continuous, then the weak topology is the weakest topology for which the functional $\int g(x)d\mu(x)$ is continuous for $\mu \in D$. Alternatively, we could give D_t the Prohorov metric, since convergence in the Prohorov distance of a sequence of measures on a Polish space is equivalent to weak convergence of this sequence (Lukacs, 1975, p. 74).

Clearly, the probability measure on Q_1 is conditioned on the realization of q_0 due to the structure of the function f. Thus, we define D_0 as the space of all Borel probability measures on $Q_0 \times D_1$. Elements of D_0 are called temporal lotteries. We introduce the following axioms on individual preferences regarding probability measures.

Axiom 6.1: The relation R is asymmetric and negatively transitive.

Axiom 6.2: The sets $[\mu_0 \in D_0 : \mu_0 R \mu_0']$ and $[\mu_0 \in D_0 : \mu_0' R \mu_0]$ are both open in the weak topology.

Axiom 6.3: If $\mu_0 R \mu_0'$ and $\alpha \in (0,1)$, then

$$[\alpha\mu_0 + (1 - \alpha) \mu_0''] R [\alpha\mu_0' + (1 - \alpha) \mu_0''].$$

Axiom 6.4: Let μ_{i0} be degenerate with outcome (q_0, μ_1). If $(q_0, \mu_1) R (q_0, \mu_1')$ and $\alpha \in (0,1)$, then

$$[q_0, \alpha\mu_1 + (1 - \alpha) \mu_1''] R [q_0, \alpha\mu_1' + (1 - \alpha) \mu_1''].$$

Axiom 6.1 and 6.2 are obvious analogs of Axiom 5.1 and the condition of Theorem 5.1 regarding continuity. Axiom 6.3 is a substitution axiom similar to Axiom 5.2 for time zero; Axiom 6.4 is a substitution axiom for time 1. The following restates Theorem 2 in Kreps and Porteus (1978).

Theorem 6.1: Axioms 6.1 to 6.4 are necessary and sufficient for these to exist continuous functions $V_1 : Q_0 \times Q_1 \rightarrow E$ and $U_0 : Q_0\ E \rightarrow E$ with U_0 increasing in its second argument such that if $V_0 : Q_0 \times D_1 \rightarrow E$ is given by

$$V_0(q_0,\mu_1) = U_0(q_0, \int V_1(q_0,q_1)\ d\mu_1),$$

then μ_0 R μ_0' if and only if

$$\int V_0(q_o,\mu_1)d\mu_0 > \int V_0(q_0,\mu_1)\ d\mu_0'.$$

Proof: Kreps and Porteus, 1978, Theorem 2.

The relationship between temporal vN-M theory as given by Theorem 6.1 and the atemporal theory studied the previous section is given by the following result.

Theorem 6.2: If $U_0(q_0,r)$ is affine in r, then the temporal respresentation collapses to the atemporal vN-M utility. This is the case if and only if, in addition to Axioms 6.1 to 6.4,

$$(q_0,\alpha\mu_1 + (1 - \alpha)\mu_1')\ I\ \alpha(q_0,\mu_1) + (1 - \alpha)(q_0,\mu_1'),$$

where I is the equivalence derived from R in the usual way.

Proof: Kreps and Porteus, 1978, Theorem 3 and its corollary.

Thus, we see that the kinds of analyses usually undertaken in the literature of option value, where atemporal vN-M utility is assumed, can be extended without modification if preferences satisfy the substitution axioms and are neutral to the resolution of uncertainty. However, it is highly unlikely that individuals are neutral with respect to the resolution of uncertainty.

We now turn to the induced preference problem and the relationship between the timing of choices of C_0 and the timing of the resolution of uncertainty. As mentioned above, induced preference generally will not have an expected utility representation. In fact, it generally will not have a temporal vN-M represenation. Kreps and Porteus (1979) derive necessary and sufficient conditions for the former to take on the latter form.

Note that in the above formulation, the first-period consumption decision was not explicitly introduced. At date zero, after observing the outcome of the temporal lottery μ_0, the agent chooses C_0 from $B(\cdot)$, the budget set. We note that it is possible to have uncertainty enter the budget set (via income or price uncertainty), so that the constraint set for time zero decisions depends on the realization of the date zero lottery, as long as it does so continuously.

In the previous section, the conditions of Theorem 5.1 were stated assuming q_0 fixed. Alternatively, we could have assumed that the individual chose (C_0,C_1) after observing the outcome of (q_0,q_1). We now uncouple these. We continue to assume preferences representable by the expectation of the continuous vN-M function V: $Q_0 \times Q_1 \times B \to E$, just as in Section V. Here, however, after observing q_0, the agent chooses C_0 maximize.

$$\int_{Q_1(\Omega)} V(q_0,q_1,C_0,C_1^*)\, d\,\mu_1.$$

We have the standout statement of the properties of value functions.

Lemma 6.2: **$V^* : Q_0 \times D_1 \to E$ defined by**

$$V^*(q_0,\, \mu_1) = \sup_{C_0 \varepsilon B(.)} \int_{Q_1(\Omega)} V(q_0,q_1,C_0,C_1^*)d\,\mu_1$$

is continuous, the supremum is attained, and c*: $Q_0 \times D_1 \to B$ is continuous.

Proof: The proof is a fairly tedious restatement of results from the dynamic programming literature (see Kreps and Porteus (1979a)) and not reproduced here; it is available from the author on request.

Induced preference can now be edfined on D_0 by

$$\mu_0 \; R_0 \; \mu_1' \text{ if } \int_{Q_1(\Omega)} V^*(q_0,\mu_1) \, d\mu_0 > \int_{Q_1(\Omega)} > V^* \; (q_0',\mu_1) \; d \; \mu_0.$$

Lemma 6.3: R_0 is asymmetric, negatively transitive, continuous, and satisfies the substitution axiom for t = 0.

Proof: Kreps and Porteus (1979) Proposition 2.

Thus, induced preference satisfies axioms 6.1 to 6.3, and by Theorem 6.1, induced preference is temporal vN-M if axiom 6.4 holds, i.e., if the substitution axiom holds for t = 1. We have the following results from Kreps and Porteus (1979).

Theorem 6.3: Induced preference is atemporal vN- if and only if, for all μ_1 and μ_1', $C_0^*(\mu_1) = C_1^*(\mu,)$.

Proof: By Kreps and Porteus (1979) Lemma 1, the $C^* : Q_0 \times D_1 \to B$ given by

$$C^*(q_0,\mu_1) = \underset{C_0 \,\varepsilon\, B(\cdot)}{\arg\max} \; V(q_0,q_1,W_0,W_1,C_0,C_1^*)d\mu_1,$$

is an upper-semicontinuous correspondence. By Proposition 2 and Corollary 1, induced preference is atemporal vN-M if and only if $C^*(q_0,\mu_1) \quad C^*(q_0,\mu_1) = 0$. Theorem 6.3 follows from this result and the fact that $C^*(q_0, \mu_1)$ is singleton-valued under the assumption of that upper and lower contour sets on D_0 under R are strictly convex sets.

Theorem 6.4: Induced preference is temporal vN-M if and only if

(i) $(q0,\mu_1) \; I \; (q_0,\mu_1')$ implies $C^*(q_0,\mu_1) = C^*(q_0, \mu_1')$

(ii) $(q_o,\mu_1) \; R \; (q_0,\mu_1')$ implies $(q_0, \alpha\mu_1 + (1 - \alpha)\mu_1') \; R \; (q_0,\mu_1)$ for all $\alpha \; \varepsilon \; (0,1)$.

Proof: Kreps and Porteus (1979), Proposition 4. Provide a statement for non-singleton C*. The result is immediate.

These results are quite strong and not easily checked. Sufficient conditions take the form of a restriction on the form of the utility function. The following result generalizes one in Kreps and Porteus (1979).

Theorem 6.5: Suppose that

$$V(q_o, q_1, w_o, w, c_o, c_1^*) = \phi_1(q_o, c_o) + \phi_2(q_o, c_o)\phi_3(q_o, q_1, c_1^*), \text{ let}$$

$$U_1(q_o, q_1, c_o^*) \equiv \phi_3 \text{ and let } u_o(q_o, \beta) \equiv \max_{c_o \varepsilon B} \phi_1 + \phi_2(\cdot)\beta \text{ for } \beta \varepsilon \tau(q_o), \text{ where}$$

$$\tau(q_o) = \{\beta \varepsilon E: \beta = \int_{Q_1(\Omega)} \phi_3(\cdot)d\mu_1 \text{ for } \mu_1 \varepsilon D_1\}.$$

Then if μ_o is strictly increasing in β, induced preference Is temporal vN-M with U_1 and μ_o representing induced preference.

Proof: It suffices to verify the substitution axiom for t =1; the result then follows from Theorem 6.1. This is obvious from the fact that V is linear and increasing in β and β is linear In μ_1. By hypothesis,

$$\max(\phi_1 + \phi_2\,\beta(\mu_1)) - \max\,(\phi_1 + \phi_2\beta(\mu_1')) > 0. \text{ But,}$$

$$\max\,[\phi_1+\phi_2\beta(\alpha\mu_1+(1-\alpha)\mu_1''))]-[\max(\phi_1+\phi_2\beta(\mu_1'+(1-\alpha)\mu_1'')]$$

$$= \max(\phi_1 + \phi_2\,\alpha\beta(\mu_1) + \phi_2(1-\alpha)\beta(\mu_1'')$$

$$- \max(\phi_1 + \phi_2\,\alpha\beta(\mu_1') - \phi_2(1 - \alpha\beta(\mu_1'')$$

$$= \max(\phi_1 + \phi_2\,\alpha\beta(\mu_1)) - \max(\phi_1 + \phi_2\,\alpha\beta(\mu_1') > 0.$$

While this condition is straightforward, it is restrictive. Kreps and Porteus (1979) develop an approximation to induced preference which is temporal VN-M, but do not claim that theirs is a "best" approximation in any sense. Machina (1982, 1984) makes use of "generalized expected utility theory," which does make use of a best approximation under the assumption that induced preferences are Frechet differential.

Before embarking on this approximation procedure, let us summarize what the issues are. The agent is assumed to have a vN-M utility function defined on (q_0, C_0, q_1, C_1). When C_1 is chosen, everything else is known. Maximizing out C_1 provides the function $V(q_0, q_1, C_0)$. Given some q_0, the distribution on q_1 is known, based on the function f. First period consumption C_0 is chosen after q_0 is observed, but before q_1 is. Thus, we can use $C_0^*(q_0, F_1(q_1 \mid q_0))$ as this optimal choice and define

$$\hat{V}(q_0) = \int V(q_0, q_1, C^*(q_0, F_1(q_1 \mid q_0)))dF_1(q_1 \mid q_0).$$

Overall rankings of temporal lotteries F_0 on $Q_0 \times \hat{D}_1$ are made on the basis of $J(F_0) = \int \hat{V}(q_0)\, dF^0(q_0)$.

Now, it is clear that preferences on temporal lotteries are linear in the probabilities given by F_0. However, the induced preferences on F_1 are <u>not</u> linear in the probabilities; Kreps and Porteus show that they are convex. Machina's (1982, 1984) insight uses intuition from ordinary calculus: a differential of a non-linear function is the best linear approximation to that function at that point. Thus, the best linear approximation to the non-linear preference functional is provided by differentiation provided it is smooth. The appropriate concept of differentiation here is Frechet differentiation.

We begin our application of Machina's analysis to the option value problem by converting the above analysis to the use of distribution functions. For each $\mu_j^i \in D_j$ there is a unique distribution function F_j^i in the space $\hat{D}_j$ of distribution function on $Q(\Omega)$. We endow the space $\hat{D}_j$ with the weak topology, as with the space D_j. Machina uses the notion of the Frechet derivative of the value functional. This requires that we define a norm on the space

$$\Delta\hat{D}_j = \{\lambda(F^* - F) \mid F, F^* \in \hat{D}_j, \lambda \in E\}.$$

Then we have the following result.

concave, then overall choices will exhibit risk aversion. Thus, we would expect results that rely solely on risk aversion to carry over to the generalized case. Unfortunately, this is not so for Bishop's proof of the non-negativity of supply-side option value. The reason is familiar: Establishing the sign of option value for supply-side uncertainty requires a singly utility function. Here, the utility function corresponding to F° is different than the utility function corresponding to F^{ν} if F° and F^{ν} are sufficiently different. Thus, for projects which significantly will affect environmental quality, the assumption Of one utility function cannot be used when there is temporal risk. Formally, we state

> Theorem 6.6: Under temporal ecological risk, the sign of supply-side option value is indeterminate, if F° and F^{ν} differ "significantly."

The main result of this section, Theorem 6.6, is a negative one. The sign of supply-side option value is indeterminate when risk is temporal under conditions that allow its determination when risk is timeless. However, Machina (1984) derives a numberof useful results concerning monotonicity and concavity of the induced utility function $V(q_o,q_1\ C^*(\cdot))$ and distribution that are ordered by stochastic dominance differ by increases in risk. We will not repeat these here; the results generally are not surprising given that most propositions in the timeless setting relying on risk aversion carry over to the temporal setting if all of the local utility functions exhibit risk aversion. While many of his results could rule out from consideration certain projects in A, it is apparent that a total ordering on A usually would not be forthcoming based on these results. For example, if a project $\hat{\nu}$ induces a distribution which differs by a mean preserving increase in risk from the distribution induced by v, then $\hat{\nu}\ P^*\ \nu$ never would hold if individual utility functions are concave in q_1. But certainly most projects of interest will give rise to changes in mean as well as increases or decreases in risk.

Of course, this does not mean that welfare evaluations cannot proceed when individual's face temporal risk. As with the static option price, we know what we wish to measure nad we have techniques available to us, contingent valuation methods, to obtain it. The relevant measure is EOP defined by

$$J(F_o^{\nu}(q),\ w) = J(F_o^{o}(q),\ w\text{-}EOP(F_o^{\nu},\ F_o^{o},\ w)),$$

where $J(F_o^{\nu}, \bullet)$ is defined as above an alternative temporal lotteries, where F_o^{ν} is the temporal lottery induced by project $\nu \varepsilon \Delta$ and 0 $\varepsilon \Delta$ is the "project" which is defined by the status-quo. What we are unable to obtain in this framework is teh sign of option value. This seems to be an elusive quest.

¯. Project Choice Under Uncertainty

As in the case of certainty, it is up to the central planner to select a project from Δ, based on individual willingness-to-pay for them. Three issues arise here. First, suppose that there is no planning uncertainty. That is, the planner is able to obtain the EOP (F°, F^{ν}, w) resource for each individual and for each $\nu \epsilon \Delta$. The analysis proceeds exactly as in Section III; based on the weights b_i of the social welfare function, the planner selects $\nu \epsilon \Delta$ such that the weighted EOP is maximal, after incorporating a feasible financing scheme for the project.

The second question that arises concerns the possibility that the planner's preferences or utilities can be formulated over projects such that the planner's preferences satisfy the von Neumann-Morganstern axioms. Clearly this will only be the case if individual utilities satisfy these axioms. Thus, in this section we consider a static model. The answer to this question, based on Wilson's (1968) analysis of the theory of syndicates, demonstrates the appeal of the linear welfare function. This is undertaken below.

The third question concerns the assumption, maintained throughout the paper so far, that uncertainty is exogenous. As Bishop (1982) points out, there is a connection between supply-side option value. The literature on quasi-option value (Arrow and Fisher, 1974), in which learning may take place.

Regarding the question of project selection, we now incorporate into the risky choice problem the financing decision, and determine a relationship between group and individual payoffs as functions of the project and outcomes of the random event.

Suppressing dependence of a previous quality, if project $\nu \epsilon \Delta$ is implemented and event $\omega \epsilon \Omega$ obtains, realized environment quality is $f(\nu,\omega)$.

Individual i's assumed von Newmann-Morganstern utility function is $V^i(q, \omega) = V^i(f(\nu,\omega)w)$ and equivalent variation is defined by

$$V^i(f(0,\omega)w^i - ev^i(\nu,\omega)) = V^i(f(\nu,\omega),w).$$

As in Section III, under financing scheme $s(\nu) \varepsilon S(\nu)$, i pays $s^i(\nu)$. The payoff to person i from implementationof project ν is $m^i(\nu,\omega) \equiv ev^i(\nu,\omega) - s^i(\nu)$.

Since environmental quality is a public good, the group payoff from implementing project ν is

$$g(\nu,\omega) \equiv \sum_i m^i(\nu,\omega) = \sum_i ev^i(\nu,\omega) - k(\nu).$$

To develop a tie to the linear welfare function of section III, we begin by supposing that the planner seeks to implement a financing scheme that is Pareto efficient.

We denote the expected utility of the ith agent under porject ν by

$$J^i(\nu,s^i(\nu), F^i) \equiv \int_\Omega V^i(f(\nu,\omega), w - s^i(\nu))dF^i(\omega).$$

The standard proofs of the following lemmata are omitted.

Lemma 7.1: The set $\tau(\nu)$ defined by $\tau(\nu) = \{J^i(\nu,s^i,F^i): \ s^i \varepsilon S(\nu)\}$ is convex.

Lemma 7.2: If $s(\nu)$ is Pareto efficient then there Is a set of weights $\{b^i(\nu), i = 1, \ldots, I\}$ with $b^i(\nu) \geq 0$ such that $s(\nu)$ solves

$$\max_{s(\nu)\varepsilon S(\nu)} \sum_i b^i(\nu) J(\nu,s^i(\nu),F^i(\omega)).$$

The following result is stated by Wilson (1968).

Theorem 7.1: $s(\nu)$ is Pareto efficient if and only if there exist non-negative weights $\{b^i(\nu)\}$ and a function $\lambda(\nu,w)$ such that

(i) $s(\nu) \varepsilon S9\nu)$

(ii) $b^i\nu \frac{\partial V}{\partial w}(\cdot)\, h^i(w) = \lambda(\nu,w)\ \lambda = 1, \ \ldots,$

for almost all w $\varepsilon\ \Omega$ for which $b^i(\nu)h^i(\omega) > 0$, where $h^i = F^i(\cdot)$, i.e., h^i is the density corresponding to i's subject probability measure on ω.

"Proof": By Lemma 7.2 the planner wishes to solve a constrained minimization problem, with weights defined by the tangent hyperplane to $\tau[\nu)$. This hyperplane exists by Lemma 7.1. The function $\lambda(\nu,\omega)$ can be thought of as the Lagrange multiplier in the constrained maximization problem, where the constraint is given by (i). Thus, $s(\nu)$ and $\lambda(\nu,\omega)$ can be found as by finding (pointwise) a paddle-point of the Lagrangean, i.e., by solving

$$\sup_{s} \inf_{\lambda} L(b^i, J^i, h^i, k)$$

where

$$L(\cdot) = \int\{\sum_i b^i(\nu)V(f(\nu,\omega),w-s^i(\nu))h^i(\omega) - s^i(\nu)\lambda(\nu,\omega)\}$$

This theorem concerns the choice of a Pareto efficient financing scheme. The central question of this analysis concerns the overall problem faced by the planner, which includes the choice of a feasible project. We wish to determine if there exists some overall utility function such that, in choosing a Pareto efficientproject, the planner will maximize the expectation of this function. The answer to this question is stated in the next proposition.

Theorem 7.2: There exists a group utility function $V^\circ(q,w)$ such that the choice of a Pareto efficient project involves solving

$$\max_{\nu\varepsilon\Delta} \int V^o(f(\nu,\omega),w)d\omega.$$

if $b^i(\nu)$ are independent of ν.

Proof: Given Theorem 7.1, the overall problem is to solve

$$\sup_{\nu\varepsilon\Delta} \int \inf_{\lambda} \{\lambda k + \sum_{i} \sup_{s\varepsilon S} [b^i V^i h^i - \lambda s^i]\} d\omega.$$

Define the "rent" measure

$$\psi^i(d_i) \equiv \sup_{x}[V^i(q,x) - d_i x].$$

Then the above problem can be simplified to read

$$\sup_{\nu\varepsilon\Delta} \int \inf_{\lambda} \{\sum_{i} [b^i h^i \psi^i(\frac{\lambda}{b^i h^i})] - \lambda k\} d\omega.$$

Define

$$V^o(f(\nu,\omega),w,\nu) \equiv \inf_{\lambda} \{\sum_{i} [b^i(\nu)h^i \psi^i(\frac{\lambda}{b^i h^i}) - \lambda k\}.$$

Then the preferred project solves

$$\sup_{\nu\varepsilon\Delta} \int V^o(f(\nu,\omega),w,\nu)d\omega.$$

This V° will depend on v only through the transition equation on environmental quality if the weights $b^i(\nu)$ are independent of ν.

The theory of syndicates, applied here to the analysis of provision of a public good, concerns the relationship between individual preference representations and group preference representations. The key result is that if the social welfare function is linear (as in Section 3), then there is a "utility function" for the planner such that choice of efficient projects amounts to maximization of the expected value of this function.

It is important to note that the only source of uncertainty in the model is ecological uncertainty. There is no planning uncertainty (in the language of Section 4) since the planner is assumed to know the individual vN-M utility functions and the individual probability density functions. With planning uncertainty, the planner does not know these individual preferences.

The case of pure planning uncertainty raises a number of interesting problems of analysis. The first concerns the form of the planner's objective function. Anderson (1979) has proposed that planner's preferences in this situation be assumed to take an expected utility form. This approach might be considered to be controverial. Second, since uncertainty gives rise to possibilities for learning, there is a possibility that the planner can devise a mechanism to discover the true preferences of individuals. This issue is the topic of the large literature on incentives. That is, can a principle (in this case the planner) design an incentive scheme which induces an agent (individuals in society who care about the project) to act in accord wtih the principle's goals (reveal their preferences for a public good). The theory of incentives has been reviewed recently by Laffont and Maskin (19820. They study particularly simple forms of individual utility functions (quasi-linear) planner choice rules which are similar to those posited here where the individual "weights" are the same for all individuals. While it appears that the literature abounds with impossibility theorems, these are often seeking incentive schemes with quite strong properties. It would seem possible for the planner to learn <u>something</u> of individual preferences which will be of use.

The third issue is that raised by the literature on quasi-option value. Until now, all of hte timing of resolution of uncertainty relative to the timing of choices in projects and consumption has been assumed exogenous. The QOV literature seeks to deduce the effect of possibilities for learning on willingness to undertake projects which are irreversible.

In terms of the current model, let $\Delta = \Delta_o \times \Delta_1$, where $\Delta_t = [0,1]$. Suppose that Int $\Delta_t = \phi$ for t = 0,1, and that projects are irreversible in that $\nu_o = 1 \Rightarrow \nu_1 = 1$, while $\nu_o = 0$ is consistent with $\nu_1 = 0$ or $\nu_1 = 1$. The QOV literature then compares two decision frameworks. In one framework it is assumed that no new information will become available. Thus, the planner chooses immediately from Δ one of (0,0), (0,1) or (1,1). In the other decision scheme a sequential decision is possible, i.e., conditional on ν_o, and the outcome of an experiment y ϵ Y that provides information, the planner chooses $\nu_1^* (\nu_o, y)$. Clearly, if ν_o = 1, then ν_1^* = 1 irrespective of the outcome of the experiment. However, if ν_o = 0, then ν_1^* (0,y) is undertaken. Using a backward induction approach, the optimal choise of ν_o can be determined based on a likelihood function for the experiment. Provided the information service Y has value (increases expected payoff) the central result of the QOV literature is that, if ν^* = (1,1) is optimal in the non-sequential decision framework, it may be that V_o^* = 0 is optimal in the sequential decision framework. The difference in expected payoff with ν_o = 1 in the non-sequential and sequential cases is QOV.

This result is intiutively plesing and corresponds to Machina's (1984) observation that an individual never will prefer a temporal prospect to an identically distributed timeless one. In the context of the current model, it appears that merely observing the outcome q_o constitutes learning since the probability distribution on q_1 is conditioned on the outcome q_o due to the nature of the transition equation f. Thus, learning here can be passive and involves no cost. Of more interest, since this surely will be recognized by a planner and built into the sequential decision framework, is the possibility of actively learning about which f ϵ Φ is the true ecological process function. An experiment which involves this additional source of learning would be sufficient for passive observation of q_o. This would give rise to an additional source of QOV.

Much of the analysis in the QOV literature assumes that Int Δ_t = ϕ, as above. Hanneman (1982) claims that QOV is not an operational concept when Δ_t is a continuum. However, Graham-Tomasi (1983) presents a model of pure planning uncertainty for the case Δ_t = [0,1] in which the concept of "quasi-option tax" (QOT) is presented. Although his model is very different than that considered here and so the details of the analysis are not relevant, his QOT is an adjustment to initial development benefits in the learning case that would lead to the same level of initial development as in the non-sequential case. Moreover, QOT is a potentially estimable number, given bythe expected present value of the second period loss if an irreversible decision is implemented at the myopically profitable level, where the loss is averaged over the possible states of nature under which the decision-maker would reverse the decision if he/she could.

8. Discussion

In this paper, we have attempted to explore the foundations of supply-side option value and project appraisal under uncertainty. The key result is the following: when temporal risk is present, the analysis of option prices and option values significantly is complicated. Since almost all situations discussed in the option value literature involve temporal risk, the analyses of this literature seriously are called into question. However, this is not really a significant insight since most of the analyses of option value have a negative result: option value is not determinate in sign. The key insight for the analytical option value literature is the following: existing studies in which positive results have been obtained, e.g., Bishop's (1982) result on supply-side option value and our own Theorem 5.6 in the same area, do not hold in an obvious way under temporal risk. As well, Freeman's (1984) and Smith's (1984) bounds on option value would need to be reexamined under temporal risk using an extension of Machina's (1984) generalized expected utility analysis to the case of state dependent preferences. An alternative is the use of the restriction of Kreps and Porteus (1979) to obtain temporal von Neumann-Morgenstern utility representations. The use of atemporal vN-M representations undoubtedly is too strong.

Another alternative to all of these machinations is to explicitly model the intervening choices, as in Drege and Modigliani (1972). This is the approach taken in the QOV literature. While a complete analysis along these lines is likely to result in too much detail so that analytical tractability is lost, for some decisions (or under separability assumptions) this may prove useful.

Regarding empirical studies, it is clear that the use of contingent valuation techniques to measure option price holds the key to correct project appraisal under uncertainty. It may turn out that empirical regularities exist. My own feeling is that this will not be the case, and such an approach is similar to the search for a single discount rate for use in the analysis of public projects. It is likely that decisions will differ sufficiently that regularities will not exist.

Regarding the conduct of these empirical studies to determine option prices, two important points emerge. When setting the context of the questions in the survey, it is crucial that respondents understand the temporal aspects of the choices being made. It is our feeling that inadequate attention has been given to this issue in existing studies. Can individuals change their minds? Will a reassessment be made as learning takes place? Need payments be equal annual payments, or can WTP lump-sum payments be allocated through time in any fashion?

A second point concerns the existence of local utility functions. The utility functions depend on initial probabilities and on all probabilities in a global analysis. This may prove to be important in the assessment procedure, particularly regarding specification bias in regressions explaining willingness-to-pay.

While the overall results of this paper seem quite negative, this is not the actual intent of the analysis. Rather, it is to suggest that much work remains to be done. But, this is not surprising given the difficulty of analyses involving both time and risk.

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APPENDIX A

AGENDA

AERE WORKSHOP ON RECREATION DEMAND MODELING
MAY 17-18, 1985
HILTON HARVEST HOUSE, BOULDER, COLORADO

SPONSORED BY:
THE ASSOCIATION OF ENVIRONMENTAL AND RESOURCE ECONOMISTS
WITH THE SUPPORT OF THE:
U.S. ENVIRONMENTAL PROTECTION AGENCY

AGENDA

AERE WORKSHOP ON RECREATION DEMAND MODELING
May 17-18, 1985
Hilton Harvest House, Boulder, Colorado

Sponsored By:
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FRIDAY, MAY 17, 1985

8:00-8:30 am SIGN-IN PERIOD AND DISTRIBUTION OF WORKSHOP PAPERS

8:30-8:45 am WELCOME AND INTRODUCTION. V. Kerry Smith, Vanderbilt University and AERE President

8:45-12:00 am SESSION I. THE TREATMENT OF SITE ATTRIBUTES IN THE MODELING OF RECREATIONAL BEHAVIOR
V. Kerry Smith, Chairperson

8:45-9:45 am "The Logit Model and Exact Expected Consumer's Surplus Measures: Valuing Marine Recreational Fishing"
Edward R. Morey, the University of Colorado and Robert D. Rowe, Energy and Resource Consultants, Inc.

9:45-10:00 am Break

10:00-11:00 am "The Varying Parameter Model: In Perspective"
William H. Desvousges, Research Triangle Institute

11:00-12:00 am "Valuing Quality Changes In Recreation Resources"
Elizabeth A. Wilman, The University of Calgary

12:15-1:30 pm LUNCH Patio Grounds or Century Room depending upon weather.
LUNCH TICKET REQUIRED.

1:40-5:00 pm SESSION II. MODELING RECREATIONAL DEMAND IN A REGIONAL SYSTEM OF SITES
Edward R. Morey, Chairperson

1:40-2:40 pm "Modeling The Demand For Outdoor Recreation"
Robert Mendelsohn, Yale University

2:40-3:40 pm "A Model To Estimate the Economic Impacts On Recreational Fishing In the Adirondacks From Current Levels of Acidification"
Daniel M. Violette, Energy and Resource Consultants, Inc.

3:40-4:00 pm BREAK

4:00-5:00 pm "Modeling Recreational Demand in a Multiple Site Framework"
Nancy E. Bockstael, The University of Maryland, W. Michael Hanemann, The University of California at Berkeley, Catherine L. Kling, The University of Maryland

5:15- pm No-Host Coctail Party. Century Room.

SATURDAY MAY 18, 1985

8:30-12:00 am SESSION III. The Definition and Estimation of Intrinsic Values Associated with Recreation Resources
Robert D. Rowe, Chairperson

8:30-9:30 am "The Total Value of Wildlife Resources: Conceptual and Empirical Issues" Kevin J. Boyle and Richard C. Bishop The University of Wisconsin, Madison

9:30-9:45 am BREAK

9:45-10:45 am "Exploring Existence Value"
Bruce Madariaga and R.E. McConnell, The University of Maryland

10:45-11:45 am "A Time-Sequenced Approach to the Analysis of Option Value"
Theodore Graham-Tomasi, The University of Minnesota

11:45- am WORKSHOP WRAP-UP
V. Kerry Smith, Vanderbilt University

APPENDIX B

LIST OF PARTICIPANTS

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May 17-18, 1985
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